

Standard Scenes Measurement Analysis & Modeling

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and Robert K. Baratonio

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FOREWORD

SWOE Report 91-15, 29 July 1991, was prepared by A.L. LaHaie, D.E. Strang and R.K. Baraton of Keweenaw Research Center, Michigan Technological University, Houghton, Michigan.

This report is a contribution to the Smart Weapons Operability Enhancement (SWOE) Program. SWOE is a coordinated, Army, Navy, Marine Corps, Air Force and DARPA program initiated to enhance performance of future smart weapon systems through an integrated process of applying knowledge of the broadest possible range of battlefield conditions.

Performance of smart weapons can vary widely, depending on the environment in which the systems operate. Temporal and spatial dynamics significantly impact weapon performance. Testing of developmental weapon systems has been limited to a few selected combinations of targets and environment conditions, primarily because of the high costs of full-scale field tests and limited access to the areas or events for which performance data are required.

Performance predictions are needed for a broad range of background environmental conditions and targets. Meeting this need takes advantage of significant DoD investments by Army, Navy, Marine Corps and Air Force in 1) basic and applied environmental research, data collection, analysis, modeling and rendering capabilities, 2) extensive target measurement capabilities and geometry models, and 3) currently available computational capabilities. The SWOE program takes advantage of these DoD investments to produce an integrated process.

SWOE is developing, validating, and demonstrating the capability of this integrated process to handle complex target and background environment interactions for a world-wide range of battlefield conditions. SWOE is providing the DoD smart weapons and autonomous target recognition (ATR) communities with a validated capability to integrate measurement, information base, modeling and scene rendering techniques for complex environments. The result of a DoD-wide partnership, this effort works in concert with both advanced weapon system developers and major weapon system test and evaluation programs.

The SWOE program started in FY89 under Balanced Technology Initiative (BTI) sponsorship. Present sponsorship is by the U.S. Army Corps of Engineers (lead service), the individual services, and the Joint Test and Evaluation (JT&E) program of the Office of the Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense (OSD).

The Program Director is Dr. L.E. Link, Technical Director of the U.S. Army, Cold Regions Research and Engineering Laboratory (CRREL). The Program Manager is Dr. J.P. Welsh, CRREL. The Integration Manager is Mr. Richard Palmer, CRREL. The task areas and their managers are as follows: Modeling Task Area, LTC George G. Koenig, USAF, Geophysics Laboratory (GL), of the Air Force Phillips Laboratories; Information Bases Task Area, Mr. Harold W. West, PE, U.S. Army Engineer, Waterways Experiment Station (WES); Scene Rendering Task Area, Mr. Mike Hardaway, Corps of Engineers, Topographic Engineering Center (TEC); Validation Task Area, Dr. Jon Martin, Atmospheric Sciences Laboratory (ASL) of the Army Materiel Command.

PREFACE

The work described in this report was performed as part of the Basic Technologies Initiative Smart Weapons Operability Enhancement (BTI/SWOE) program, under contract number DACA89-89-K-0012 managed by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL).

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1.0. INTRODUCTION

The work described in this report was performed as part of the Smart Weapons Operability Enhancement (SWOE) program, a cooperative tri-service research effort funded as part of the Basic Technology Initiative (BTI) program. Among the primary goals of the BTI/SWOE program have been development of a quantitative treatment of the environment in critical spectral bands, and the collection, evaluation, and integration of representative data and information bases. KRC's participation in the BTI/SWOE program has included contributions in the program's three primary developmental areas:

1. Background measurement and characterization;
2. Information data base;
3. Modeling - scene metrics.

1.1 Background Measurement and Characterization

Environmental conditions significantly affect the thermal infrared signature of targets, and the detectability of those targets by sensors operating in the 8 – 14 μ m range. The collection of detailed measurements of the background environment, and the analysis of those measurements in order to characterize the background are important preliminary steps toward incorporating a comprehensive understanding of the environment to the design and testing of smart weapons systems.

As part of a cooperative data collection and information exchange effort of the BTI/SWOE, Keweenaw Research Center (KRC) participated in the 1990 Forest Ecosystem Dynamics - Multisensor Aircraft Campaign (FED MAC) project, conducted at the International Paper National Experimental Forest (NEF), near Howland, Maine. This work was conducted in order to acquire information useful for model validation, and for establishing the needs and directions of future BTI/SWOE measurement programs.

KRC collected thermal, optical, radiative and meteorological measurements of forest canopy elements to support the following objectives:

1. Model vegetative leafy canopies with emphasis on conifers;
2. Investigate the soil temperature distribution along the forest edge;
3. Model "twiggy" canopy with emphasis on a single, deciduous tree.

From 0800 on 9 September, 1990 to 1330 on 11 September, 1990, KRC personnel recorded thermal imagery at two sites, on an hourly basis, with additional imagery recorded during periods of particular interest. During this same time period, extensive meteorological and soil temperature data were also recorded. The sites selected and data collected in support of each objective are discussed separately below, in Section 5.1.1.

1.2 Information data base

Among the long-term goals of the BTI/SWOE program is that of assembling and validating environmental databases, tailored for weapon development, test and evaluation.[1] The generation of such an information database involves two preliminary, general areas of endeavor. It is necessary to develop a database structure to accommodate the large amount of information collected during measurement and characterization activity. More analytical work is required to determine possible scene conditions and features of interest, those scene conditions most likely to occur, and those that are most significant to the function of target detection.

The U.S. Army Tank-Automotive Command (TACOM) Standard Scenes data base,[2] developed by KRC, represents a compendium of ground truth, scene component data, meteorological data and concurrent, calibrated infrared imagery for six scenes. Data had been collected on these scenes for full diurnal cycles at different times across 3 years, thus affording information about the scenes under a range of meteorological and seasonal conditions. General climate and physical features of Standard Scenes are comparable to those of parts of Germany.[3] Inasmuch as German sites represented one of the three scenarios of interest in the BTI/SWOE program (the other scenarios being desert and tropical), the Standard Scenes data base provides relevant information. KRC's experience with developing this database also provides a useful basis for appraisal of database developmental needs and directions.

1.3 Modeling and simulation

The design, development, and testing of smart weapons can benefit from greater understanding of the variations in radiometric properties of natural background scenes. These variations reflect some underlying, physical variation of the background. Describing scene components directly in terms of their image properties allows more general measures of shape, intensity, texture, and spatial arrangement to be the critical factors in discriminating between different scene elements.

Predicting radiometric variability of natural backgrounds involves several activities. First, the radiometric properties of specific scene elements must be determined. The covariation between these radiometric properties and related, quantifiable scene characteristics - e.g., material properties, meteorological, climatic, and atmospheric conditions, and time - must be evaluated. On the basis of this information, algorithms to predict variations in the radiometric properties of specific scene elements can be developed. Finally, the interaction between radiometric and physical properties of the scene and sensor system performance is evaluated.

1.3.1 Scene Metrics

Performance goals of automatic target recognition algorithms are to detect and select targets in real time, and to be able to adapt to dynamic physical and tactical situations. Testing ATR algorithms under a range of physical conditions involves: 1) specifying an appropriate data base, 2) training and evaluating feature classification algorithms and decision criteria on the data base to determine the most efficient sets of algorithms for specific task objectives, and 3) determining the requirements for data bases of imagery representative of specific scenarios.

2.0. OBJECTIVES

2.1 Background Measurement and Characterization

KRC provided personnel, equipment, and facilities to conduct measurements of natural backgrounds, including 1) site composition inventory, and 2) time-dependent, calibrated thermal imagery, with simultaneous weather and scene parameter measurements, in support of the cooperative data acquisition and exchange program involving BTI/SWOE and the Forest Ecosystem Dynamics/Multisensor Aircraft Campaign (FED MAC) experiment.

2.1.1 FED MAC Field Test Objectives

The FED MAC experiment, conducted at International Paper's Northern Experimental Forest near Howland, Maine, included several specific objectives relating to radiative transfer processes in northern/boreal forest ecosystems. These objectives included developing a better understanding of the transfer and utilization of radiation in forest canopies, and enhancing the development of quantitative modeling of radiative transfer process in northern forest environments.[4] These objectives were to be achieved through collection of detailed field experimental data. Specific objectives defined for KRC participation in the FED MAC project are detailed below.

Vegetative Leafy Canopies: Edge Dynamics.

The thermal behavior along the edge of a natural forest, at its interface with open, grassy field, was to be investigated. A particularly interesting feature of the site selected for this purpose was a large, narrow gap in the forest edge, which afforded a clear view of the forest interior. In addition to characterizing the site, immediate field test objectives were to collect measurements and thermal imagery of 1) simple, homogeneous (*i.e.*, single species) portions of the forest canopy, viewed from short-range or in magnification, 2) clumps of single-species vegetation along the edge, viewed from short- to intermediate-range, and 3) mixtures of deciduous and coniferous species in the forest canopy. The goals of obtaining this imagery

were to document thermal infrared radiance patterns of component parts of the forest canopy, and to provide data to support simulation of canopy temperature patterns.

Soil Temperature Transect into Forest Edge.

The objective of performing a soil temperature transect was to monitor soil temperatures at various points, from an exposed area in an open field to points progressively deeper within the forest canopy. Thermocouple probes had to be devised to measure and record a profile of soil temperature at various depths.

Single, Isolated Tree Thermal Response.

Thermal infrared imagery and supporting weather data were acquired by KRC to support an investigation of the thermal response of an individual tree, conducted by Sparta, Inc. The purpose of this effort was to document thermal response of component parts of a single tree to transient changes in environmental conditions.

2.2 Information data base

The Standard Scenes database was to be organized and structured to make it compatible with modeling community needs. The Standard Scenes database was to be made available to the modeling community.

On the basis of experience gained from establishing the Standard Scenes database, KRC was to provide ideas to help develop a database structure that would accommodate the large amount of information collected during measurement and characterization activity.

2.3 Modeling and simulation

In the context of BTI/SWOE goals regarding the prediction of radiometric variability, KRC was to assist in calculating statistics for scene structure, and in adapting or improving infrared models/software to include calculation of various measures of scene characteristics. The Physically Reasonable Infrared Signature Model (PRISM) was also to be delivered and integrated to the initial BTI/SWOE software capabilities.

2.3.1 Scene Metrics

In the context of BTI/SWOE goals regarding scene structure vs. metrics, KRC was to function in a support role, assisting in the analysis of selected infrared scene metrics and

other measures of image and scene elements that are linked to background material properties. Infrared models/software already developed by KRC were to be improved to compute additional statistics describing scene features, and measures such as scene clutter.

3.0. CONCLUSIONS

3.1 Conclusions - Background Measurement and Characterization

KRC participation in the FED MAC experiment has generated thermal infrared imagery and supporting measurements that are being incorporated to the database being established cooperatively for that effort. The imagery and field data have been reduced to computer files and analyzed by KRC personnel. Results of the study of forest edge dynamics, and the soil temperature transect of the forest edge are discussed in the context of this report. In its support capacity for the study of thermal response of a single tree, KRC has provided imagery, digitized image files, and supporting data to Sparta, Inc. Copies of thermal infrared imagery have also been provided to C2NVEO.

KRC also prepared for participation in another BTI/SWOE field test which was originally planned to take place in Yuma, Arizona, in August, 1990.

3.2 Conclusions - Information Data Base

The Standard Scenes database developed by KRC was made available for integration to the BTI/SWOE information base.

Interaction between agencies cooperating in BTI/SWOE program has provided insight to the information needs and format requirements of the modeling community, at large.

3.3 Conclusions - Modeling and Simulation

The PRISM software was made available for integration to the BTI/SWOE suite of modeling and simulation packages. The newest release of PRISM provides full three-dimensional faceted representation of a vehicle, and has been enhanced by the inclusion of the following

capabilities: facet-to-facet radiation exchange, multiple bounce solar radiation, long- and short-wave shadowing, multiple bounce radiosity, and target signature visualization. This 3-D version of PRISM is available as of July, 1991.

The principal application of PRISM is the predictive modeling of the thermal signatures of military vehicles; it previously had not been used for background scene generation, and hence was not evaluated in detail in the context of the BTI/SWOE program.[5] A modified version of PRISM is presently being developed to predictively model thermal behaviour of natural objects, e.g., a tree, and natural terrain. The database created as part of participation in the BTI/SWOE "Background Measurement and Characterization" activities provide quantitative information useful in the process of developing and validating these models.

In its support role regarding scene metrics, KRC tested a Pascal program developed by Waterways Experiment Station, "SCENEMEZ", on selected Standard Scenes imagery. Discussion relating to this effort is provided both in the main body of this report, and also in Appendix D.

4.0. RECOMMENDATIONS

4.1 Recommendations - Background Measurement and Characterization

The original Standard Scenes database did not include measurements of long-wave incoming radiation, although subsequent KRC field tests do include this variable. It is useful in prediction of radiometric variability, and is incorporated in computations in PRISM and related codes. From test to test in a given site, it is recommended that the following parameters be measured and recorded at appropriate frequencies (suggested frequencies are shown), and in a consistent format:

1. Geophysical and meteorological parameters (see Section 5.1.3.; twelve times per hour)
2. Vertical profiles of soil and air temperature and three-axis wind velocities, at various points in the scene (12 times per hour)
3. Snowpack thermal profile (if applicable; 12 times per hour)
4. Water content of scene surface (once per hour)
5. Spot radiometric measurements of selected scene component surfaces (once per hour, or as local conditions dictate)
6. Soil moisture profile (dependent on precipitation; 4 times per diurnal test)
7. Tree canopy leaf area index (LAI) (if applicable; twice per diurnal test)
8. Vegetation status (once per test)

Characterization of the atmosphere or the monitoring of other thermal and millimeter wave properties of scene components should be determined by the importance of evaluating such factors as sensor system characteristics and the range at which sensors are expected to operate.

4.2 Recommendations - Information Data Base

Thermal infrared imagery obtained at intermediate range and from elevated or aerial perspective with varying depression angles is definitely of interest in applications involving smart weapons. Standard Scene VI is the only scene in the KRC database that affords a lookdown perspective from a significant elevation. Although the BTI/SWOE effort has served to bring together a variety of scenes from disparate data bases, further development and characterization of scenes imaged at various ranges and depression angles is recommended, as well as the incorporation of blackbodies at various ranges for calibration purposes.

4.3 Recommendations - Modeling and Simulation

Continuing problems include the difficulty in obtaining source code for programs, programs that contain machine-specific commands that require adaptation to run on different systems, and programs that contain proprietary subroutines that are difficult to obtain or difficult to integrate on a different system. Every effort should be made to further the goals of standardization, and complete documentation of subroutines and subprograms to ease the work of adapting software to new systems.

Continued development of three-dimensional, first principles models of natural backgrounds should remain a strong goal of this program. Refinement of techniques for assessing target recognition performance in the infrared domain is also recommended.

5.0. DISCUSSION

5.1 Background Measurement and Characterization

5.1.1 Advance Preparation for Field Testing

Preparation for field work on background characterization involved several significant activities, including remodeling the interior and exterior of the KRC mobile lab/equipment bus, shown in Figure 5.1 to condition it for travel to remote field test sites. Some alterations to the lab/bus were made for the purposes of safety: high intensity driving lights were installed for improved vision in fog, snow, or night driving; back-up lights and more visible turn signals were installed; a mechanical-ride driver's seat was put in; and a weather radio and speakers were installed to provide weather monitoring and warnings during field tests. A new heater was also installed, along with a separate battery and battery isolator to operate the heater in case of power failure. Other alterations enhanced the capabilities of the mobile lab: the vehicle was wired to accept 120 vac. shore or generated power including a circuit breaker panel with a relay to switch to either generated or shore power; electrical strip outlets to power equipment were installed; interior lighting was improved; and a higher output alternator was installed to accommodate new accessories. A final series of alterations improved equipment storage and accessibility on the lab/bus.

Table 5.1 lists principal equipment provided by KRC for the FED MAC experiment. The AGEMA infrared scanning system was acquired for this project. The twelve ground surface thermocouples included in the Meteorological Station listing were specifically devised for the soil temperature transect detailed in Section 5.1.3. Post-hoc analysis of equipment requisites for the FED MAC test showed the equipment list to be adequate; possible additions would be to include more sets of blackbodies, shielded thermocouples on individual stands, and portable spot radiometers.

5.1.2 Field Test Sites and Details of Experimental Plans

KRC set up equipment and performed measurements at two sites in the International Paper National Experimental Forest (NEF), near Howland, Maine. As described in following sections, the two sites are near to each other and data was recorded consistently and with near simultaneity at both sites across a two and a half day period. The KRC primary site was set up to provide data relating to the objectives of studying edge dynamics of vegetative leafy canopies, and of investigating changes in soil temperature in the forest edge. The KRC secondary site provided data supporting the investigation of thermal dynamics of an individual tree.

KRC Primary Site.

The primary site for KRC measurement activities is located north of the NEF calibration ("CAL") site, and west of the tree seed orchard, as shown in Figure 5.2. This site was selected for several reasons: 1) it affords a good perspective of a forest edge, 2) the forest edge includes a good mix of deciduous (predominantly yellow birch and poplar) and coniferous (spruce and hemlock) species, and 3) a large gap in the forest edge affords opportunities both for imaging the forest interior, and also for investigating the dynamics between the forest's edge and interior.

The KRC primary site is located in an open field that slopes slightly down to a treeline having a south-by-southeastern exposure. The field is comprised of patches of grassy vegetation, mosses, and bare sandy or rocky soil. The forest edge is dominated by younger, deciduous trees and bushes; behind and above these, the crowns of more mature, predominantly coniferous trees are clearly visible. The gap in the vegetation at the forest edge measures 9 feet at its narrowest spot, and affords a clear view of the trunks and crowns of large spruce and hemlock in the forest's interior.

Infrared imagery of the forest edge and gap was obtained from two points, as shown in the site schematics in Figures 5.3 and 5.4. The soil temperature transect was established in the gap area. Figure 5.5 provides a schematic of the soil probe placement, and identifies probes both by thermocouple depth and by the channel on which their output was recorded. The KRC meteorological tower and station were also set up at this site. The photograph in Figure 5.6 provides a visual perspective of the KRC primary site.

KRC Secondary Site.

The secondary site for KRC measurement activities is located adjacent to the NEF calibration ("CAL") site, just south of the monitoring equipment building (see Figure 5.2). This site was the location of the single poplar tree (*Populus grandidentata*) selected for study by Sparta, Inc. Sparta personnel conducted extensive measurements on this tree and placed a large number of thermocouples on it. KRC supplemented the Sparta thermal measurements with thermal imagery of the tree, along with meteorological data recorded at the KRC primary site.

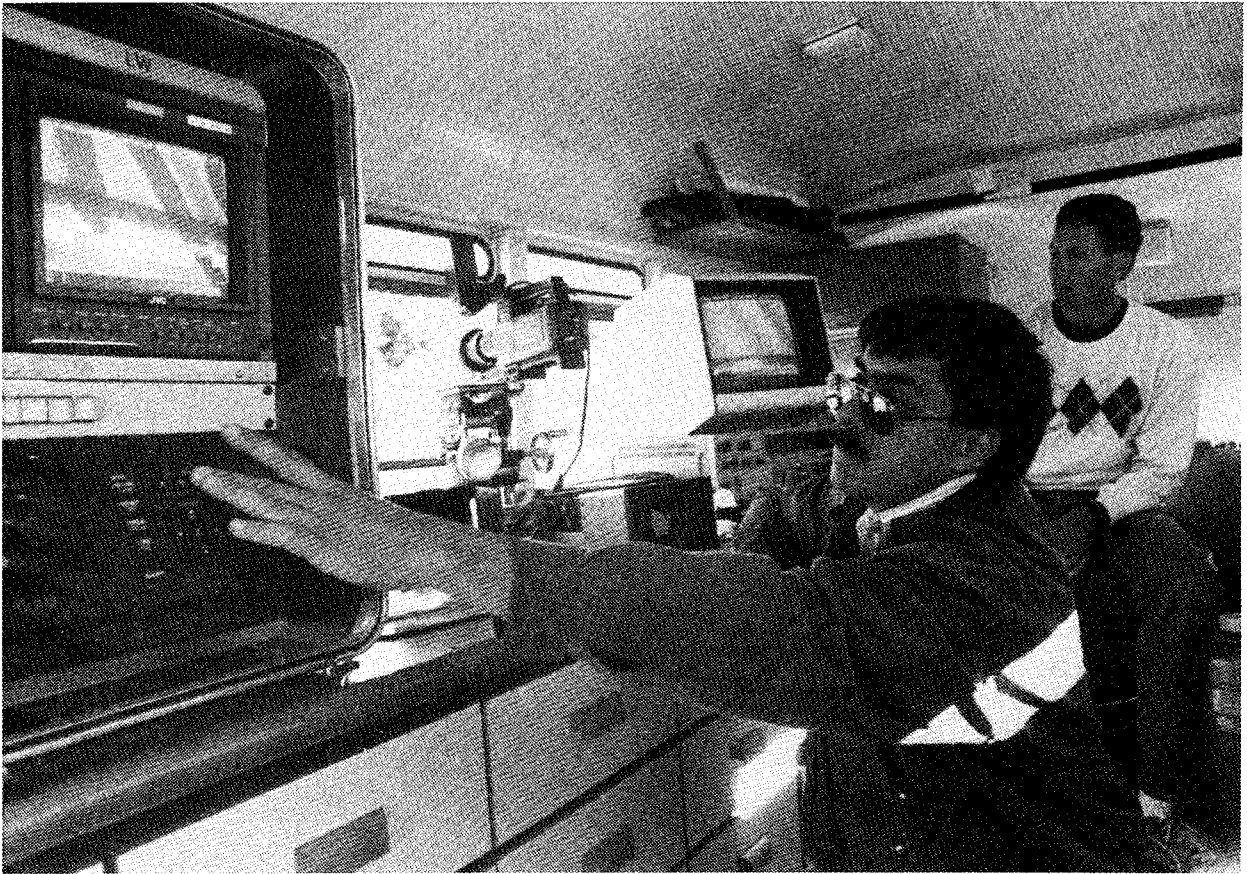


Figure 5.1: KRC Mobile Lab/Equipment Bus Interior, Photographic View

KRC personnel are shown setting up and testing equipment inside the mobile lab. At the study site in the Northern Experimental Forest, Maine, this equipment was used to record thermal infrared imagery of a natural, forested background scene, and related physical measurements.

Table 5.1: Principal equipment provided by KRC for the FED MAC experiment.

Keweenaw Research Center Equipment List

Item	Serial #	MTU Tag
Meteorological Station		
IBM PC computer		59597
IBM PC monitor		64576
EPSON printer	512301	
DORIC Digitrend 235		61806
AMS-5PA Amplifier	1333	
Voltage stabilizer		81887
Multipoint Selector		61798
IR Sensors(3)	26480F3 (1)	67665, 67666 (2)
Wind Speed Velometer		61835
10m portable weather tower		
Ground probe		
12 ground surface thermocouples		
Honda (6kw) generator		67669
Blackbody Ambient		
Blackbody Heated		69850
Campbell Thermocouple loggers(2)		65860, 67656
12V batteries for loggers(2)		
Infrared Scanning Equipment		
Inframetrics 610 IR Camera	7133	
Inframetrics 3x lens	7133	
JVC Monitors		67747, 67748
Inframetrics Controller		67749
Agema IR Scanner w/lens	003005	
Agema Controller	00272	
Agema Power Supply(s)	3249, 9006S, 90069	
Agema Monitor	001043	
Monitor		61829
Sanyo Monitor	12104034	
Barnes radiometer		62103
Tektronix 2213 Oscilloscope		
Recording Equipment		
SONY VO-7600 U-matic recorders		15819, 15494
U-matic recording tapes		
Video Camera (VCR)		
VHS tapes		
Miscellaneous		
Toshiba portable computer		71332
Honda generator in bus		64141
Sanyo microwave oven		
Tool Kit		
Dewer, 30L (2) Liquid Nitrogen		
Dewer, 5L (2) Liquid Nitrogen		
3.5in and 5.25in diskettes		
Realistic TRC210 radios(2)		61857, 61864
LICOR LAI-2000 in case	below	
LAI-2700 logger		71333, 71334
LAI-2500 radiation detector		71335, 71336
Misc. connectors, cables		

The KRC secondary site is an open area from which dense, bushy vegetation – e.g., blackberry bushes, poplar saplings and other small, deciduous trees – had been recently removed in order to isolate the single poplar selected for study. KRC imaging equipment was set up to the northwest of the tree, as shown in the site schematic in Figure 5.7 and the photograph in Figure 5.8.

5.1.3 Data Acquisition

Calibrated Thermal Imagery.

Thermal imagery was collected using two commercially available IR imaging systems: an Inframetrics model 610 was used at the primary site, and an AGEMA Thermovision 880 at the secondary site. Specifications for the imagers are detailed in Table 5.2. Each frame of thermal imagery is reference to an apparent temperature or blackbody equivalent temperature standard via the near simultaneous acquisition of frames showing a pair of blackbodies, one of which is maintained at ambient temperature and the other heated to a temperature near the warmest observed in the scene. The temperature of the heated blackbody is actively controlled, and both blackbodies are monitored with thermocouples that are read directly into the weather data logger.

Field Test Procedure.

Soil probes were placed on 7 September, 1990, and thus had more than 24 hours to re-equilibrate before data was recorded. As may be seen in Figure 5.9, the soil around the first probe was disturbed during the placement procedure. The other probes were placed with much less disturbance of the soil, as may be seen in the photographs in Figures 5.10, 5.11, and 5.12. In addition to the weather variables discussed in the following section, the KRC meteorological station computer recorded data for all 12 soil probes transecting the forest edge, the main soil probe located near the meteorological tower in open field, shown in Figure 5.13, and the shielded thermocouple for measuring air temperature that was placed at the forest edge, as shown in Figure 5.14. Measurements were automatically recorded every five minutes.

Thermal imagery was recorded at hourly intervals, or more frequently during periods when environmental conditions caused thermal activity in the scenes to change or vary. At the KRC primary site, calibrated thermal imagery included views of the following scenes: gap area (1X lens), an area to the left of the gap with predominantly deciduous trees (3X lens), a close-up view of the gap (3X lens), and an area to the right of the gap with a mix of deciduous and coniferous species (3X lens). At the KRC secondary site, calibrated thermal imagery was taken of the lower half of the isolated tree, and occasionally of the upper half of the tree.

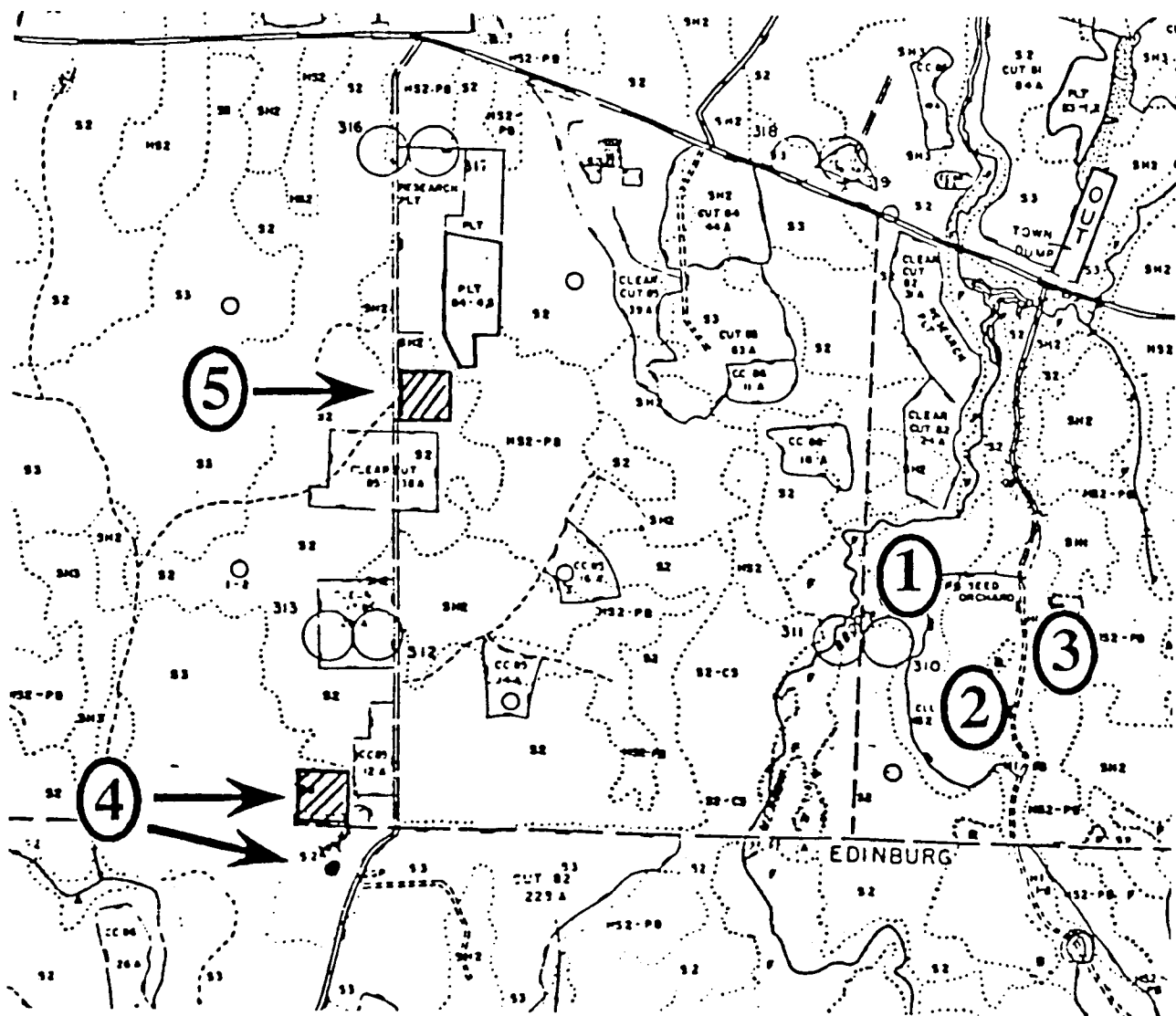


Figure 5.2: Map of International Paper's Northern Experimental Forest.

1. KRC Primary Site
2. Calibration Site (KRC Secondary Site)
3. Esker Site
4. Spruce Site (top)
Tower Site (bottom)
5. Hemlock Site

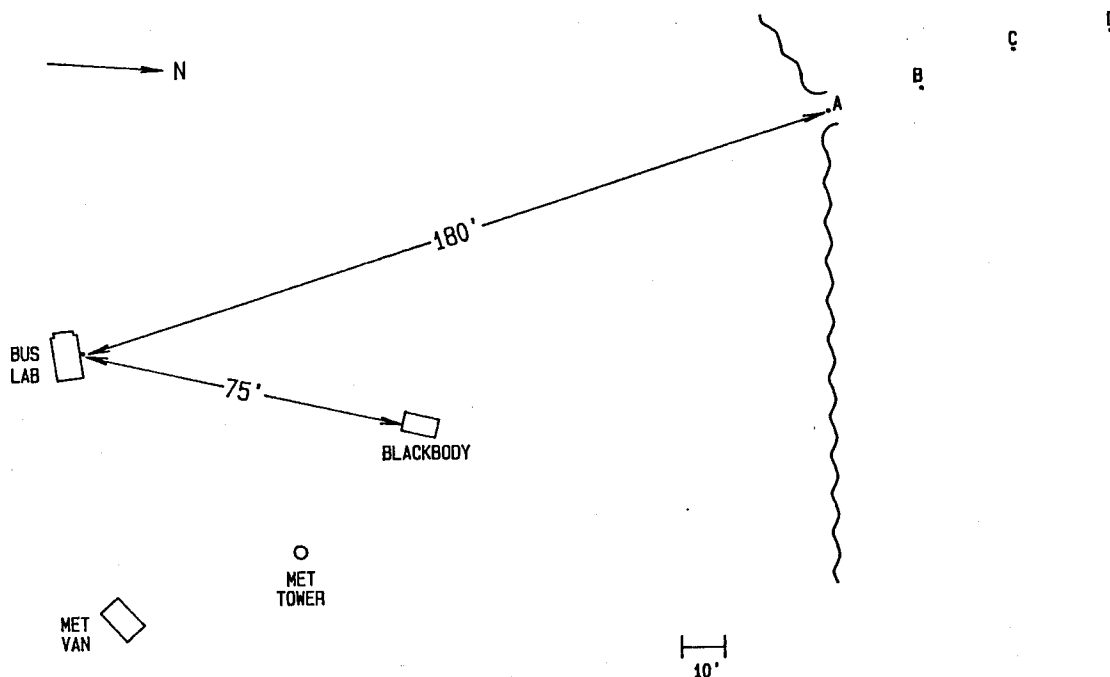


Figure 5.3: Schematic of KRC Primary Site, 09 September, 1990.

Positioning of soil probes, blackbodies, weather station and van, and imaging bus lab are shown in relation to the forest edge, as they were for imagery taken during the first 24 hour cycle of the field test.

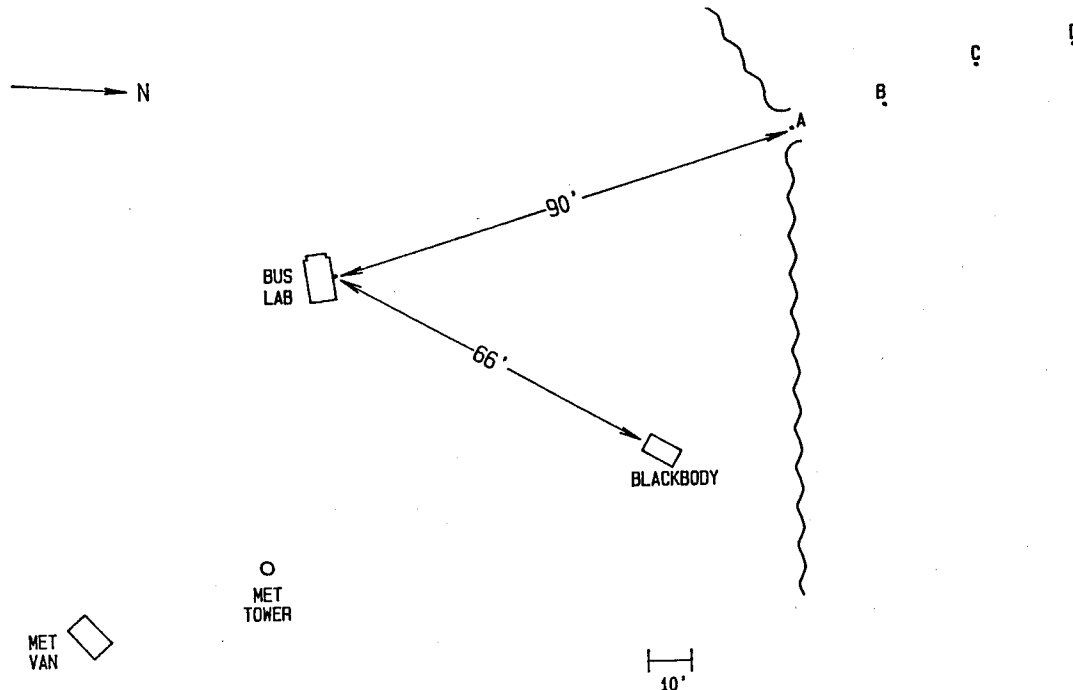


Figure 5.4: Schematic of KRC Primary Site, 10 September, 1990.

Positioning of soil probes, blackbodies, weather station and van, and imaging bus lab are shown in relation to the forest edge, as they were for imagery taken during the second 24 hour cycle of the field test.

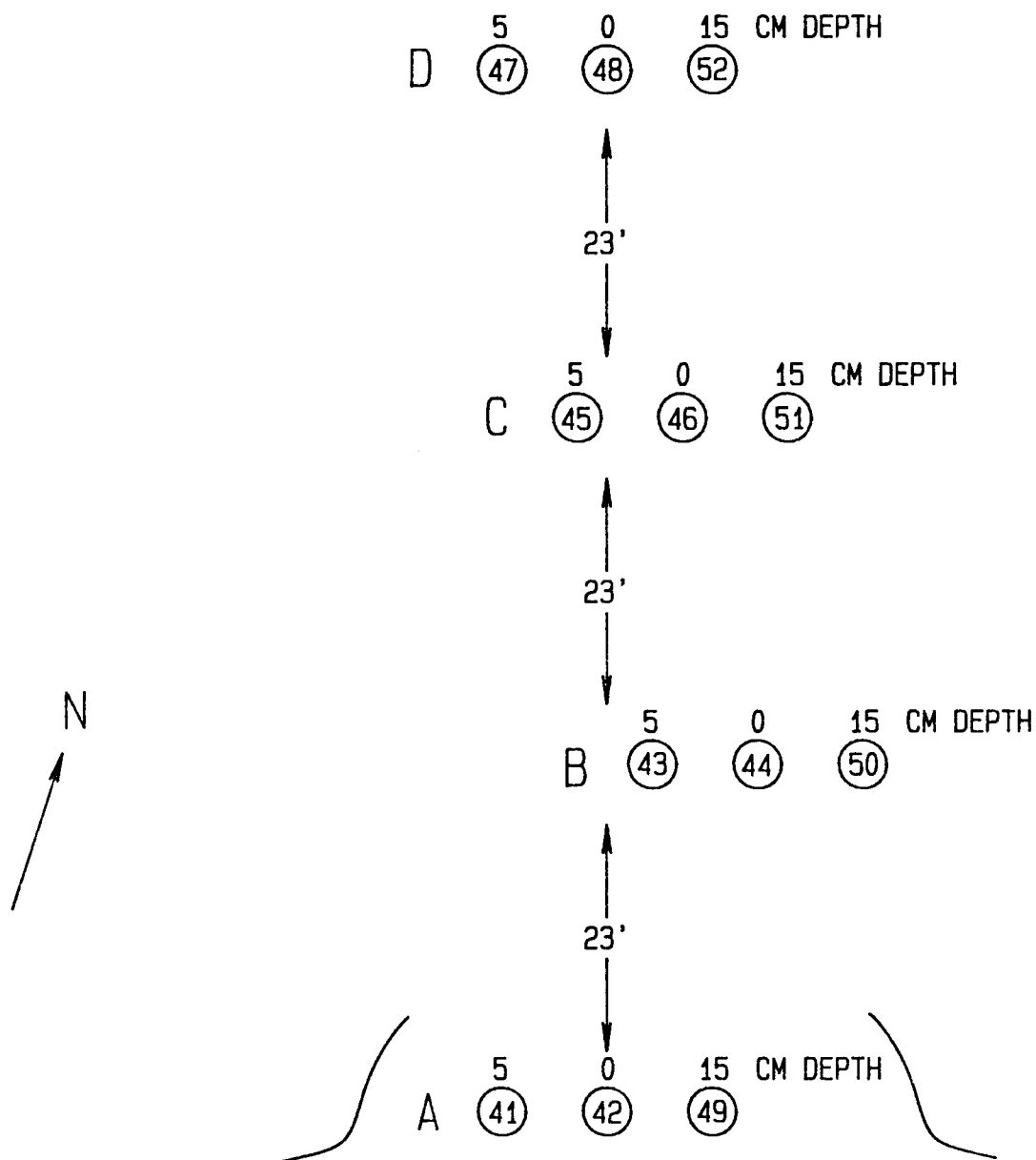


Figure 5.5: Schematic of Thermocouple Placement for Soil Transect, KRC Primary Site.

Groups of three probes were placed at 0 cm, 5 cm and 15 cm depths at each of four locations: in the gap at the field/forest edge interface (A), at the open gap/closed canopy interface (B), a short way into the forest interior (C), and a spot deeper in the forest interior (D) that received little direct sunlight.



Figure 5.6: KRC Primary Site, Photographic View.

Geophysical and meteorological parameters.

The weather and soil parameters recorded automatically by the on-site weather station are listed below. Solar irradiance data is sampled once per minute; all other quantities are sampled once every five minutes.

- o global solar irradiance (0.285 - 2.8 micrometers)
- o longwave incoming radiation (3.0 - 50.0 micrometers)
- o air temperature (0, 1, 2, 3, & 5 meters above ground)
- o wind speed (0, 2, & 8 meters above ground)
- o wind direction (8 meters above ground)
- o dew point (degrees Celsius)
- o barometric pressure (millibars)
- o soil temperature profile (0, 0.01, 0.05, 0.1, 0.2, & 0.5 meter depths)

Field personnel regularly write down observations regarding cloud conditions, cloud cover, atmospheric conditions, precipitation, and related phenomena. These observations are entered on the thermal imagery log sheet.

Measurements of leaf area index and mean tip angle (LAI/MTA) in the forest canopy were obtained using a LICOR LAI-2000 Plant Canopy Analyzer. These measurements are presented and discussed in Appendix A. The measurements of apparent temperatures of scene components obtained with a hand-held spot radiometer are also reported in Appendix A.

30

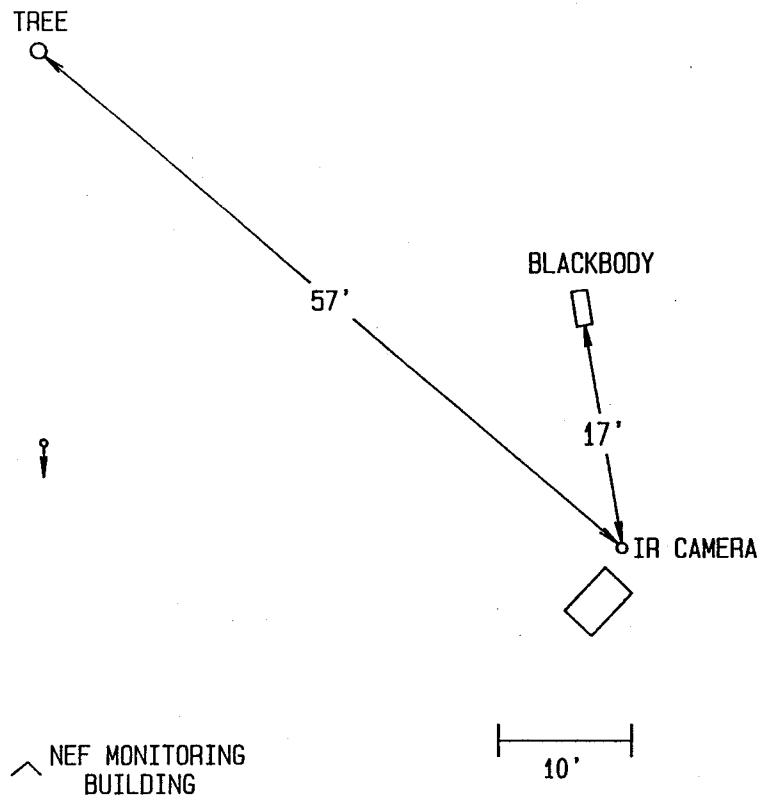


Figure 5.7: Schematic of KRC Secondary Site, 09 - 11 September, 1990.
Positioning of blackbody, IR camera and monitoring and recording equipment are shown in relation to the study tree and NEF monitoring building.



Figure 5.8: KRC Secondary Site, Photographic View.

Table 5.2: Thermal Imager Specifications.

Specification	Inframetrics 610		AGEMA 880
Lens	1x	3x	1x
Dynamic range (levels)	128	128	*
Vertical FOV (mrad/deg)	261(15)	87(5)	349(20)
Horizontal FOV (°/°)	347(20)	116(6.7)	349(20)
LWIR band:			
Spectral bandpass (um)	8-14	8-14	8-12
Vert./Horz/ IFOV (mrad)	2.0	0.67	175 elt/line
NETD	0.2	0.2	0.2
NETD-16 frame avg.(°C)	0.05	0.05	0.02
MDT (°C)	0.1	0.1	*

* Not available.



Figure 5.9: Location A Ground Probes, Soil Temperature Transect.



Figure 5.10: Location B Ground Probes, Soil Temperature Transect.

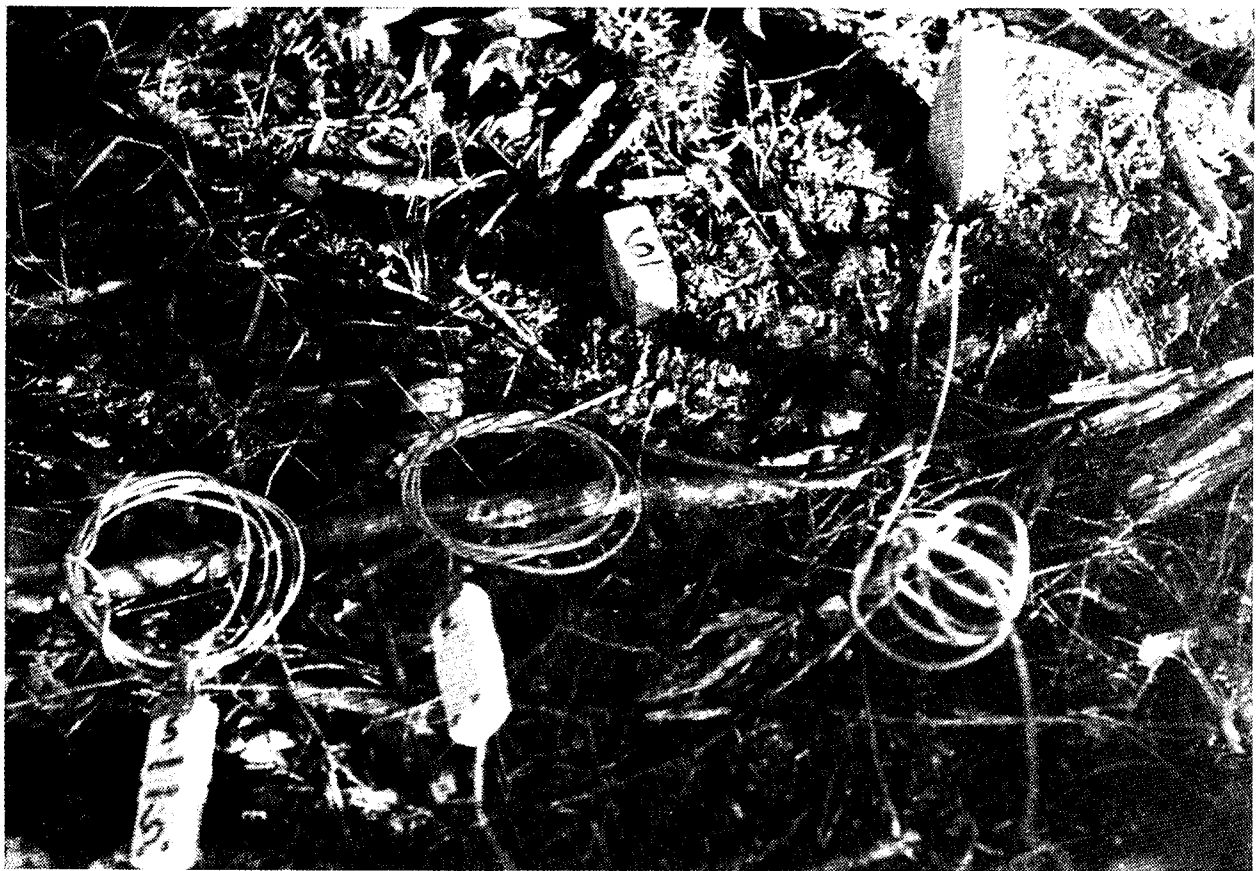


Figure 5.11: Location C Ground Probes, Soil Temperature Transect.



Figure 5.12: Location D Ground Probes, Soil Temperature Transect.

5.1.5 Thermal Imagery

Description of Thermal Imagery and Data.

Thermal imagery is digitized for processing using a PC-based Data Translation frame grabber. Each binary digit frame is supplemented by information from the corresponding frame of blackbody imagery, and converted into a calibrated temperature pixel frame. The temperature value assigned to a pixel is an apparent, or blackbody equivalent temperature, i.e., a blackbody at that temperature would emit the equivalent amount of radiation, in band, that was detected by the thermal imager.

Thermal Imagery, Primary Site.

Examples of the background scenes for which thermal imagery was recorded at the KRC primary site are shown in figures on the following pages. The view referred to as "deciduous" consisted of a dense, brushy deciduous bushes and trees along the forest edge just to the west of the gap, and is shown in Figure 5.16. Thermal images of the gap area, itself, are shown in Figures 5.17 and 5.18. A final view, designated "mixed" in reference to the mix of deciduous and coniferous species present along the forest edge just to the east of the gap, is shown in Figure 5.19. Figure 5.20 is an example of the thermal imagery of the blackbody pairs, which was obtained for calibration purposes. Complete listings of image frames and descriptions of file formats are provided in Appendix A.

Thermal Imagery, Secondary Site

Examples of thermal imagery of the single poplar recorded at the KRC secondary site are shown in Figures 5.21 and 5.22. Complete listings of image frames and descriptions of file formats are provided in Appendix A.

5.1.6 Vegetative Leafy Canopies: Edge Dynamics

The sets of thermal infrared imagery obtained at the KRC Primary Site permitted thermal behaviour of various scene components to be examined and compared across time. Statistics for areas of deciduous vegetation are compared with those for areas of coniferous vegetation in Figures 5.23 through 5.26. These statistics were generated by identifying image sub-regions of coniferous and deciduous vegetation, respectively, in calibrated imagery of "mixed species" along the forest edge, and processing these sub-regions in each image frame. Each figure compares statistics for deciduous vs. coniferous vegetation for a specific twelve-hour period: Figure 5.23 shows relatively low thermal activity overnight, following a heavily overcast day; Figure 5.24 shows results for an overcast day with clouds thinning and abruptly clearing at about 1745, in the afternoon; variable clouds and fog affect overnight conditions shown in Figure 5.25; and Figure 5.26 shows the response of vegetation to conditions of variable clouding, with alternating periods of cloud shadow and of strong sunlight.



Figure 5.13: Meteorological Tower and Main Ground Probe, in Open Field.



Figure 5.14: Shielded Thermocouple for Air Temperature, Forest Edge.


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Time: 16:25   Date: 09/10   Sky Temp: 18.532 C
1 Solar Radiation..... 189.749 W/m^2
3 LWIR Batt. (1.35v).. 1.345 V
7 Doric Temp..... 20.500 C
21 Wind Direction..... 169.038 Deg.
23 Wind Speed 2 m..... 0.818 m/sec
25 Air Temp. 5 m..... 16.900 C
27 Air Temp. 2 m..... 16.800 C
29 Air Temp. 0 m..... 17.200 C
31 Soil Temp. 1 cm..... 18.800 C
33 Soil Temp. 10 cm..... 17.900 C
35 Soil Temp. 50 cm..... 17.900 C
40 Terrain Albedo..... 34.400 W/m^2
42 TC 0cm dn Loc A.... 17.800 C
44 TC 0cm dn Loc B.... 16.300 C
46 TC 0cm dn Loc C.... 15.500 C
48 TC 0cm dn Loc D.... 15.300 C
50 TC 15cm dn Loc B.... 14.800 C
=====
2 Longwave IR..... 409.570 W/m^2
5 Barometric Press.... 1016.270 mB
18 Diffuse Radiation... 156.680 W/m^2
22 Wind Speed 8 m..... 1.277 m/sec
24 Wind Speed 0 m..... 0.655 m/sec
26 Air Temp. 3 m..... 16.900 C
28 Air Temp. 1 m..... 17.200 C
30 Soil Temp. 0 cm..... 18.800 C
32 Soil Temp. 5 cm..... 18.400 C
34 Soil Temp. 20 cm.... 17.400 C
36 Relative Humidity... 95.460 %
41 TC 5cm dn Loc A.... 16.900 C
43 TC 5cm dn Loc B.... 15.400 C
45 TC 5cm dn Loc C.... 14.300 C
47 TC 5cm dn Loc D.... 13.800 C
49 TC 15cm dn Loc A.... 15.700 C
51 TC 15cm dn Loc C.... 13.800 C
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Time: 16:30   Date: 09/10   Sky Temp: 18.125 C
1 Solar Radiation..... 162.819 W/m^2
3 LWIR Batt. (1.35v).. 1.345 V
7 Doric Temp..... 20.600 C
21 Wind Direction..... 178.470 Deg.
23 Wind Speed 2 m..... 0.879 m/sec
25 Air Temp. 5 m..... 17.100 C
27 Air Temp. 2 m..... 17.100 C
29 Air Temp. 0 m..... 17.300 C
31 Soil Temp. 1 cm..... 19.000 C
33 Soil Temp. 10 cm.... 17.900 C
35 Soil Temp. 50 cm.... 17.900 C
40 Terrain Albedo..... 27.800 W/m^2
42 TC 0cm dn Loc A.... 18.000 C
44 TC 0cm dn Loc B.... 16.400 C
46 TC 0cm dn Loc C.... 15.600 C
48 TC 0cm dn Loc D.... 15.400 C
50 TC 15cm dn Loc B.... 14.800 C
=====
2 Longwave IR..... 407.287 W/m^2
5 Barometric Press.... 1016.180 mB
18 Diffuse Radiation... 139.361 W/m^2
22 Wind Speed 8 m..... 1.111 m/sec
24 Wind Speed 0 m..... 0.065 m/sec
26 Air Temp. 3 m..... 17.100 C
28 Air Temp. 1 m..... 17.300 C
30 Soil Temp. 0 cm..... 19.100 C
32 Soil Temp. 5 cm..... 18.500 C
34 Soil Temp. 20 cm.... 17.400 C
36 Relative Humidity... 94.475 %
41 TC 5cm dn Loc A.... 16.900 C
43 TC 5cm dn Loc B.... 15.400 C
45 TC 5cm dn Loc C.... 14.300 C
47 TC 5cm dn Loc D.... 13.800 C
49 TC 15cm dn Loc A.... 15.600 C
51 TC 15cm dn Loc C.... 13.800 C
=====

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Figure 5.15: KRC Meteorological Station Hardcopy Printout, Example.

Statistics of variation and second-order statistics were also calculated for deciduous and coniferous image sub-regions, in order to compare the distributions of apparent temperature values across time and under various physical conditions. Figures 5.27, 5.28, and 5.29 summarize the standard deviation, skew, and kurtosis, respectively, for deciduous vs. coniferous vegetation. The strongest variations in skewness and kurtosis occur during periods of minimal overall variation in temperature, and thus are probably of little information value. The most significant portions of these graphs are along the rightmost edges, the time period from 0700 to 1300 on 11 September, 1990. Variable meteorological conditions during this period contributed to higher and more variable temperatures, as indicated by the relatively large standard deviations in Figure 5.27; skewness and kurtosis are consistently nominal during this same time period, suggesting a very normal temperature distribution for vegetation.

Thermal infrared imagery of the gap in the forest edge provided an opportunity to analyze several different scene components simultaneously. As well as showing patches of (predominantly deciduous) vegetation along the edge and patches of vegetation recessed within the shaded interior of the forest, these images also clearly show trunks of both live and dead trees. Statistics were calculated for image sub-regions and are shown in the following set of figures: Figure 5.30 shows apparent temperature range and average for vegetation along the forest edge adjacent to the gap; Figure 5.31 for vegetation within the gap, in the forest interior; Figure 5.32 for the trunk of a live spruce tree visible in the gap; and Figure 5.33 for the trunk of a dead spruce tree visible in the gap. Descriptions of statistics files for these scene components are also given in Appendix A.

Contrasts in the thermal behaviour of these diverse scene elements are more clearly evident in the comparisons of averages shown in Figures 5.34, 5.35 and 5.36. In Figure 5.36, in particular, it may be seen that both transient and overall responses to increased solar loading (on the rightmost segment of graph) are very different for live vs. dead vegetation, and for leafy vegetation vs. the tree trunk.

5.1.7 Soil Temperature Transect into Forest Edge

The soil temperature transect recorded data at various soil depths and locations, at the KRC primary site during the FED MAC 1990 experiment. Data was collected from sets of thermocouples set into the soil at three different depths - 0 cm (soil surface), 5 cm, and 15 cm - at each of four locations - labelled A, B, C, and D - in the forest edge, and recorded at five minute intervals. A schematic of the thermocouple probe locations was given in Figure 5.5, earlier in this report.

Figures 5.37 through 5.40 graphically depict the soil temperature data recorded at all depths (0, 5, and 15 cm.) at locations A, B, C, or D, respectively, across time. Figures 5.41, 5.42, and 5.43, on the following pages, graphically compare readings from probes set at a specific depth at all locations, across time.

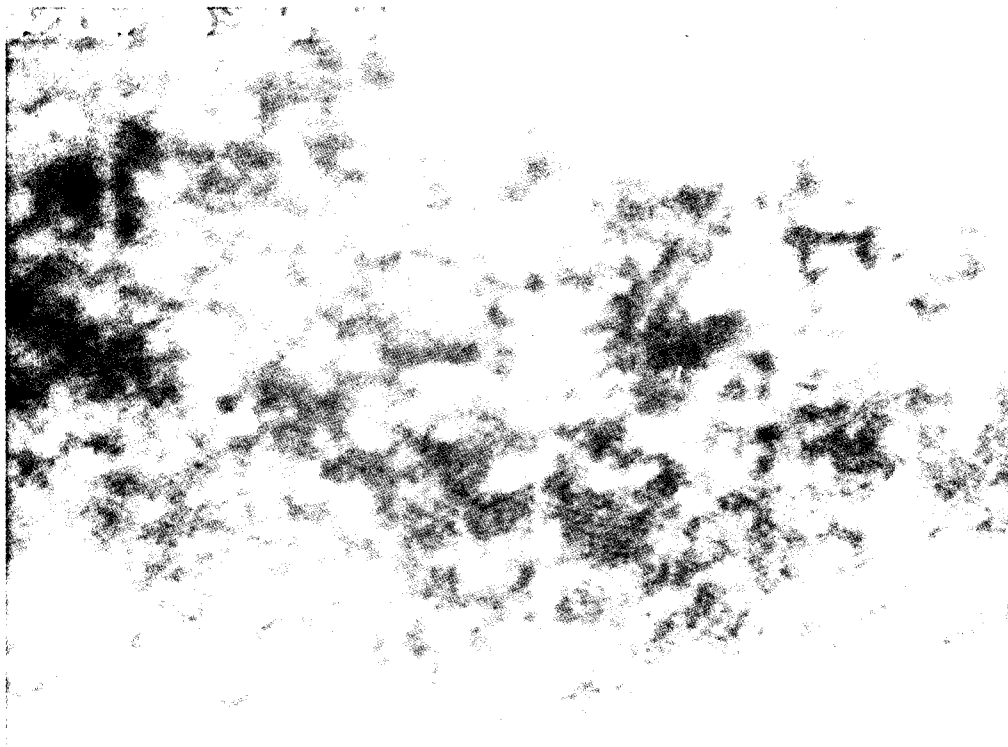


Figure 5.16: Infrared Imagery of Deciduous Vegetation at Forest Edge, West Side of Gap, Inframetrics 610, 3X Lens, 8 – 14 μ m.



Figure 5.17: Infrared Imagery of Forest Gap Inframetrics 610, 1X Lens, 8 – 14 μ m.

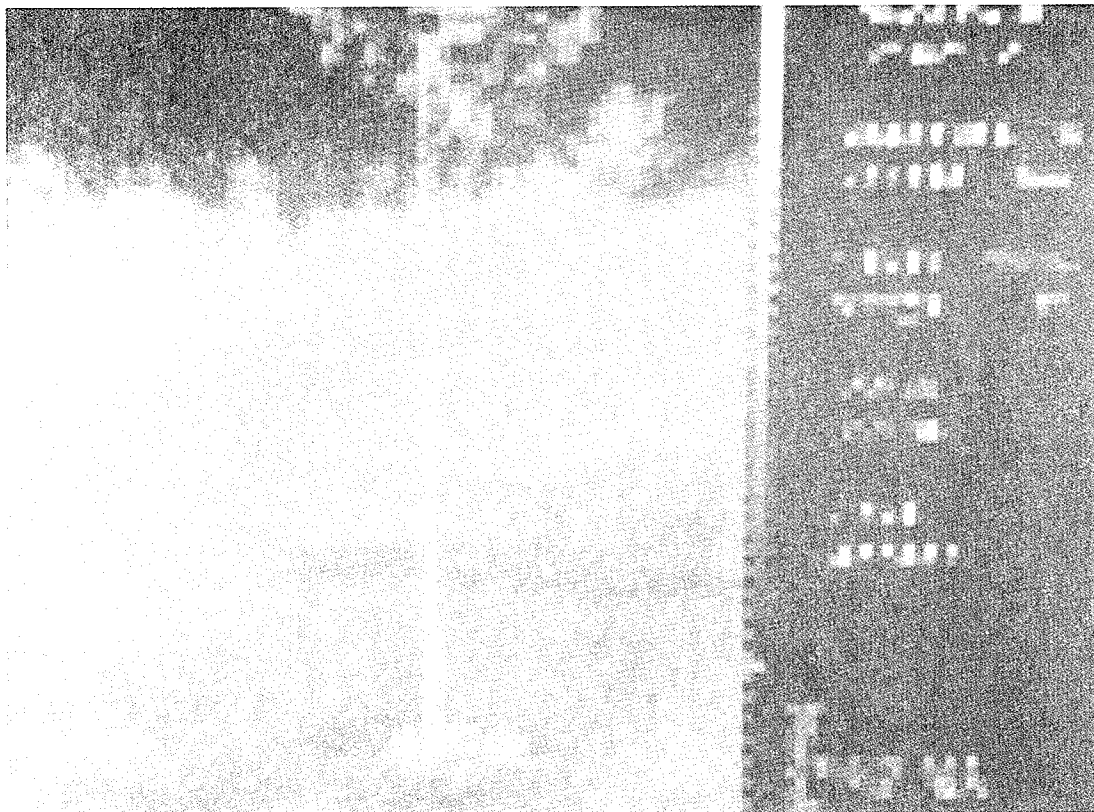


Figure 5.21: Infrared Imagery of Single Tree, Trunk and Lower Branches from AGEMA 880, 8 – 14 μ m.

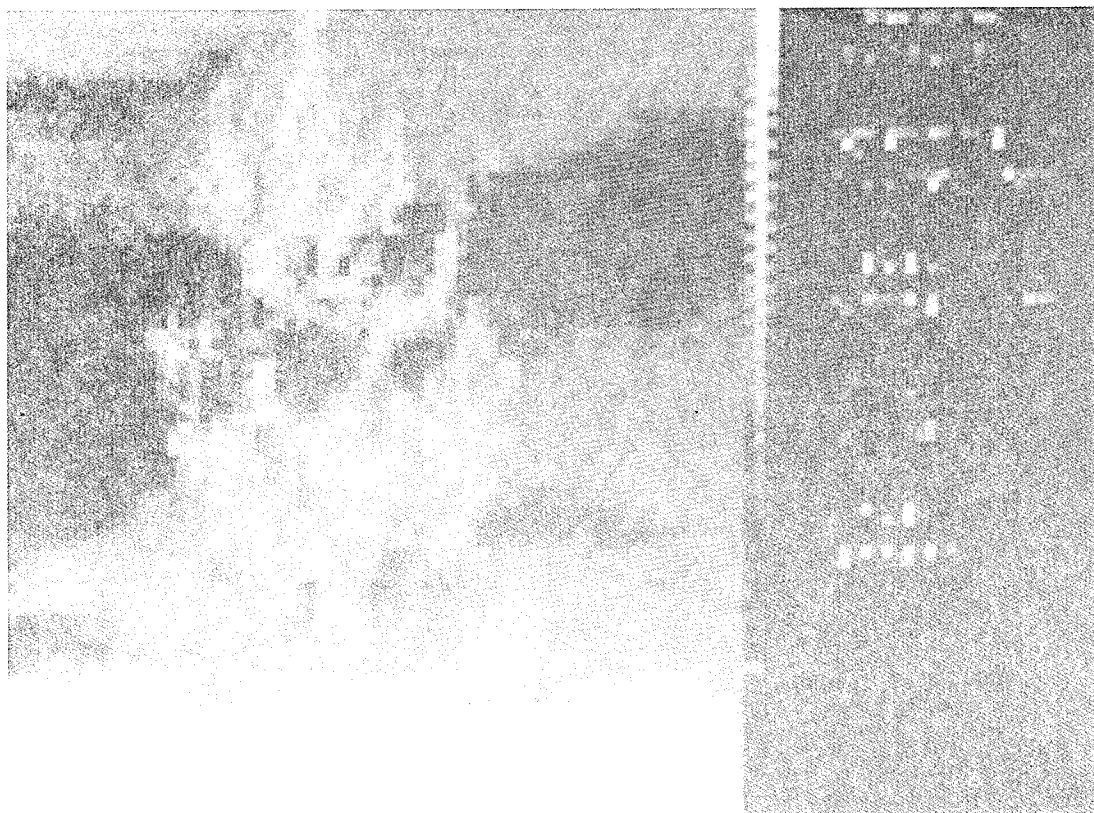


Figure 5.22: Infrared Imagery of Single Tree, Crown from AGEMA 880, 8 – 14 μ m.

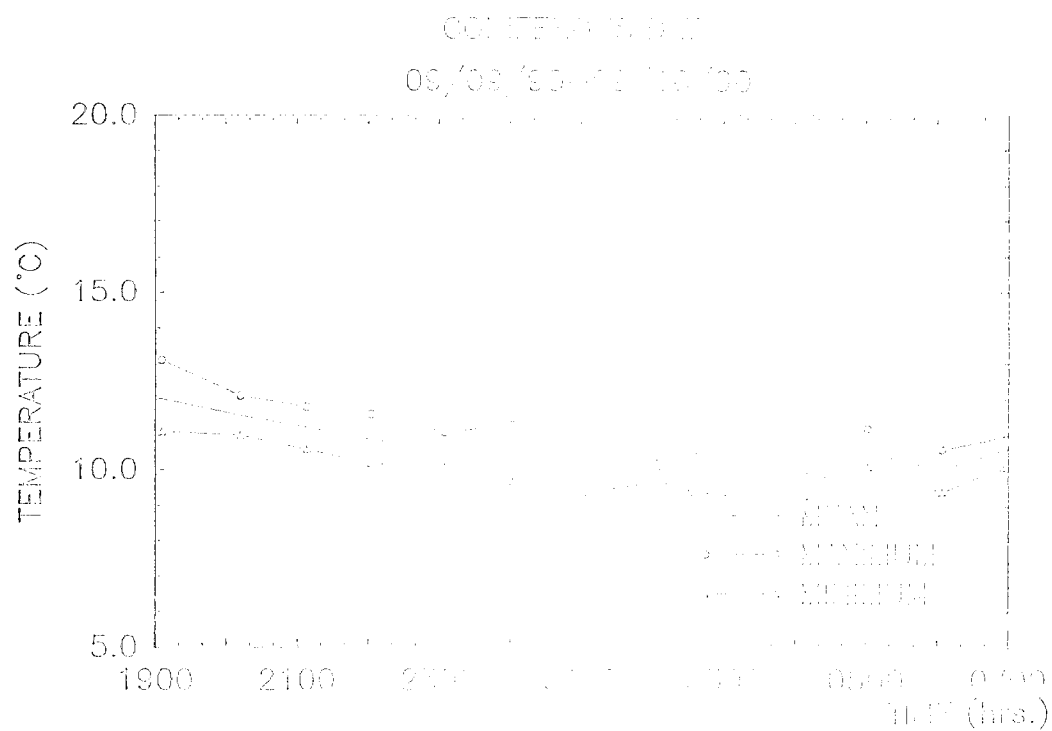
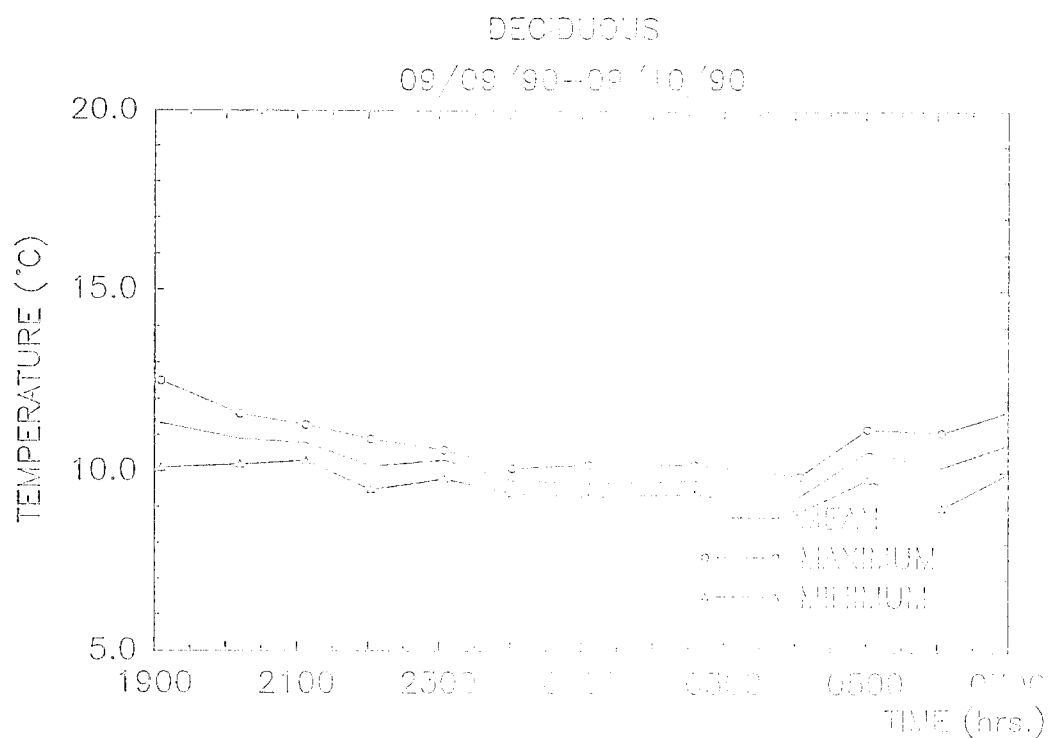


Figure 5.23: Descriptive statistics for the 24-hour period of Forest Vegetation. Shown Across Time for one day (09/09/90-09/10/90) for mean, max, min. 1900 through 0700 hours on 10 September, 1990.

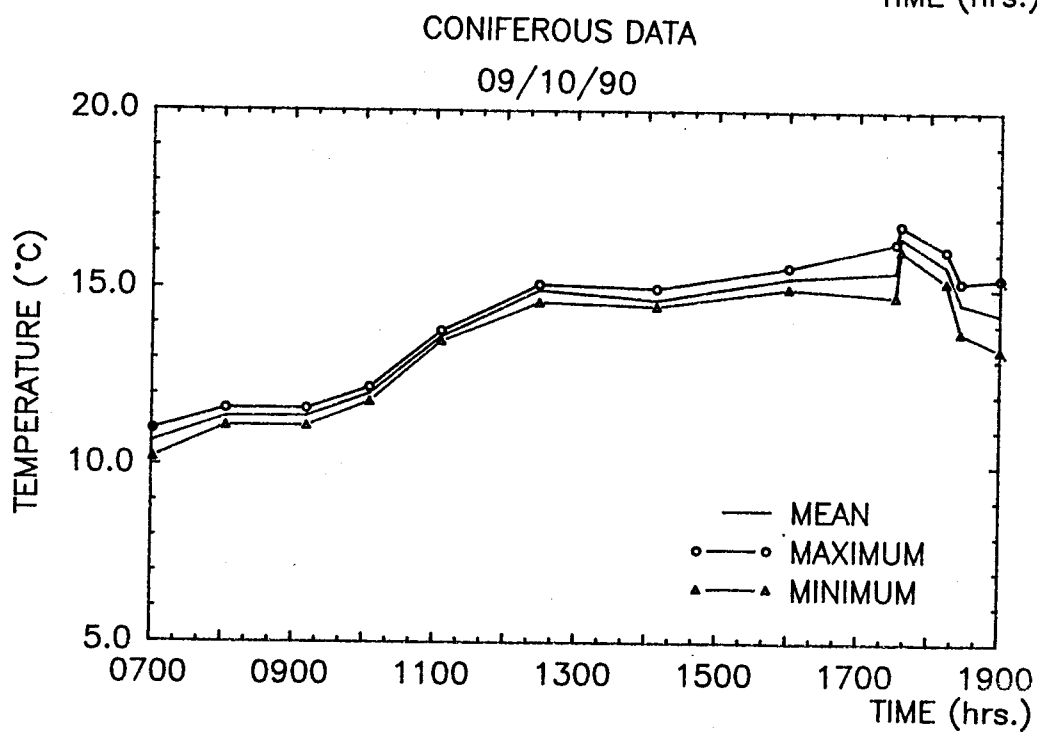
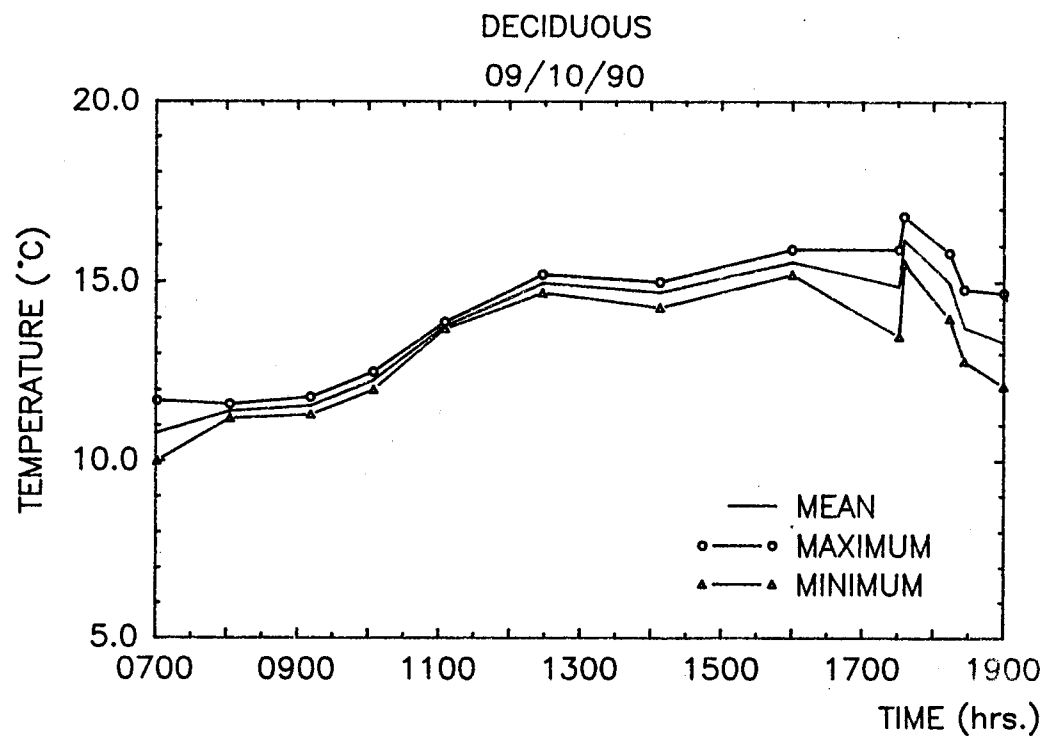


Figure 5.24: Descriptive Statistics for Deciduous and Coniferous Vegetation.
Shown Across Time for daytime period from 0700 hours through 1900 hours on 10 September, 1990.

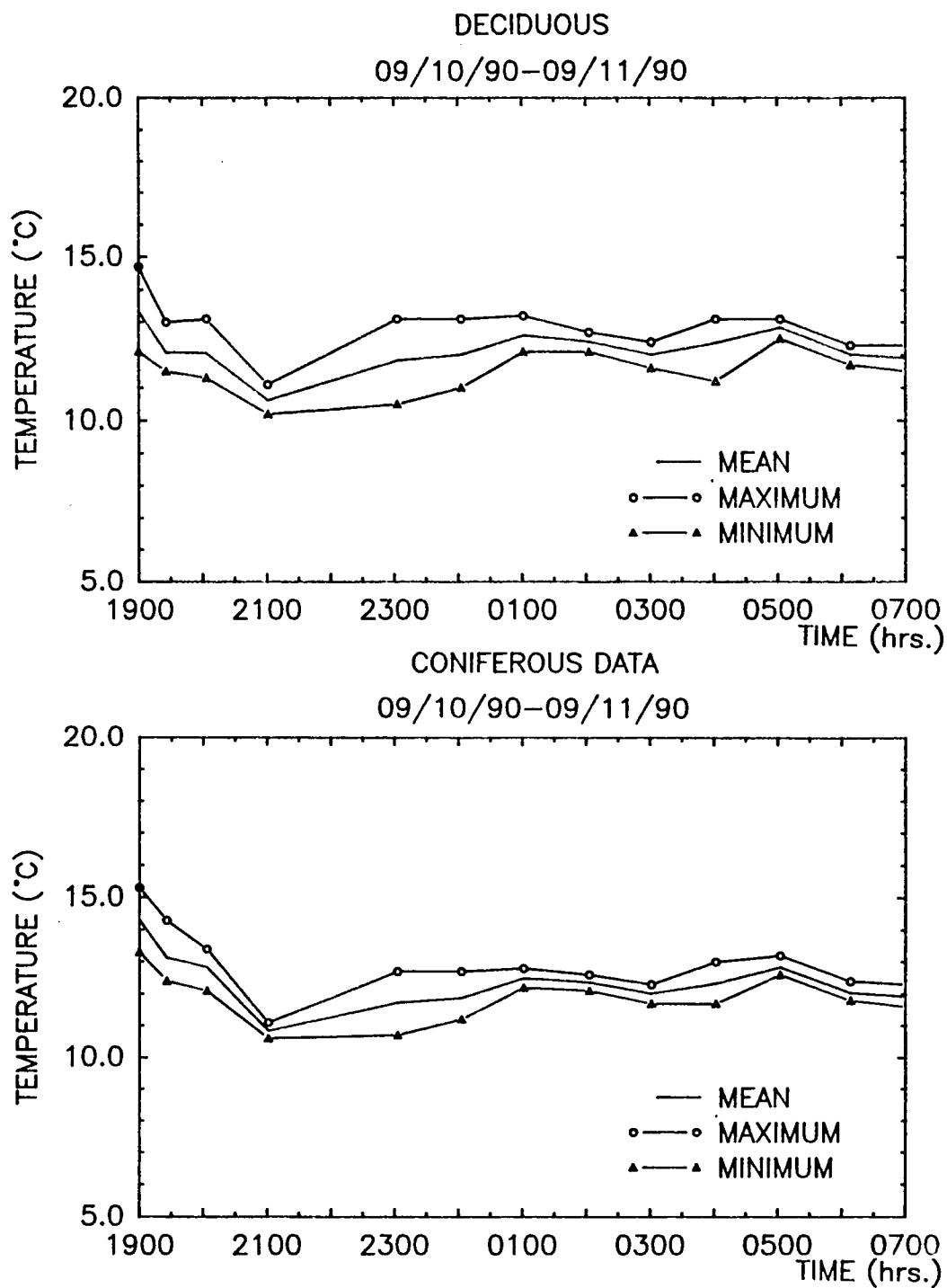


Figure 5.25: Descriptive Statistics for Deciduous and Coniferous Vegetation
Shown Across Time for overnight period from 1900 hours on 10 September, 1990 through 0700 hours on 11 September, 1990.

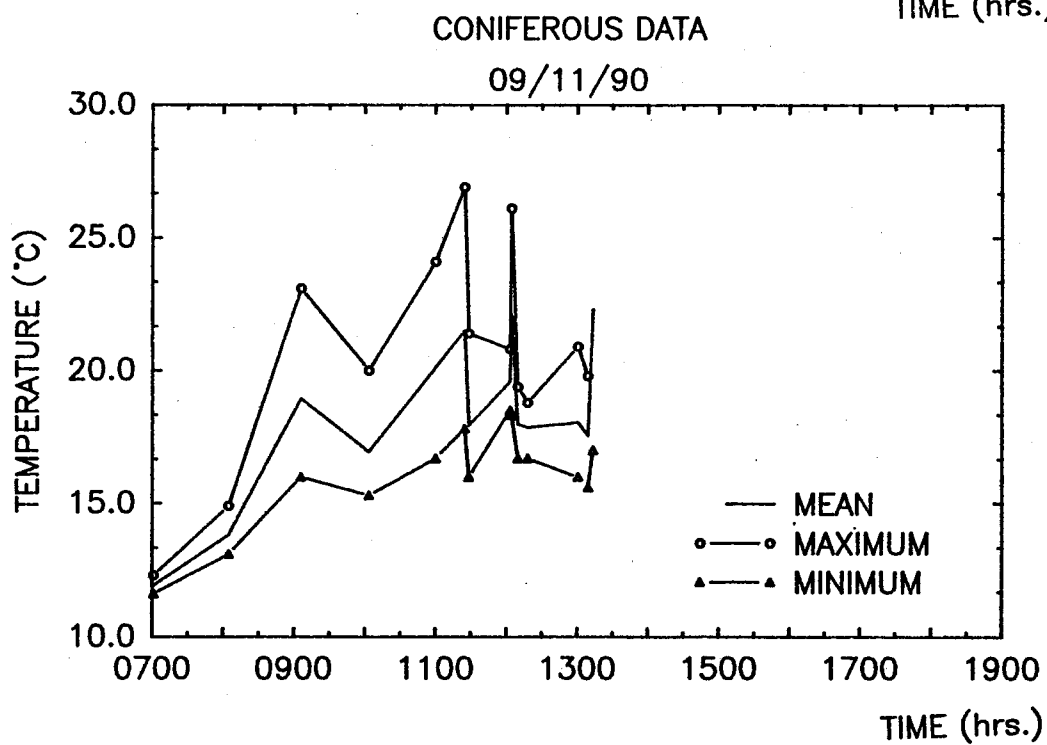
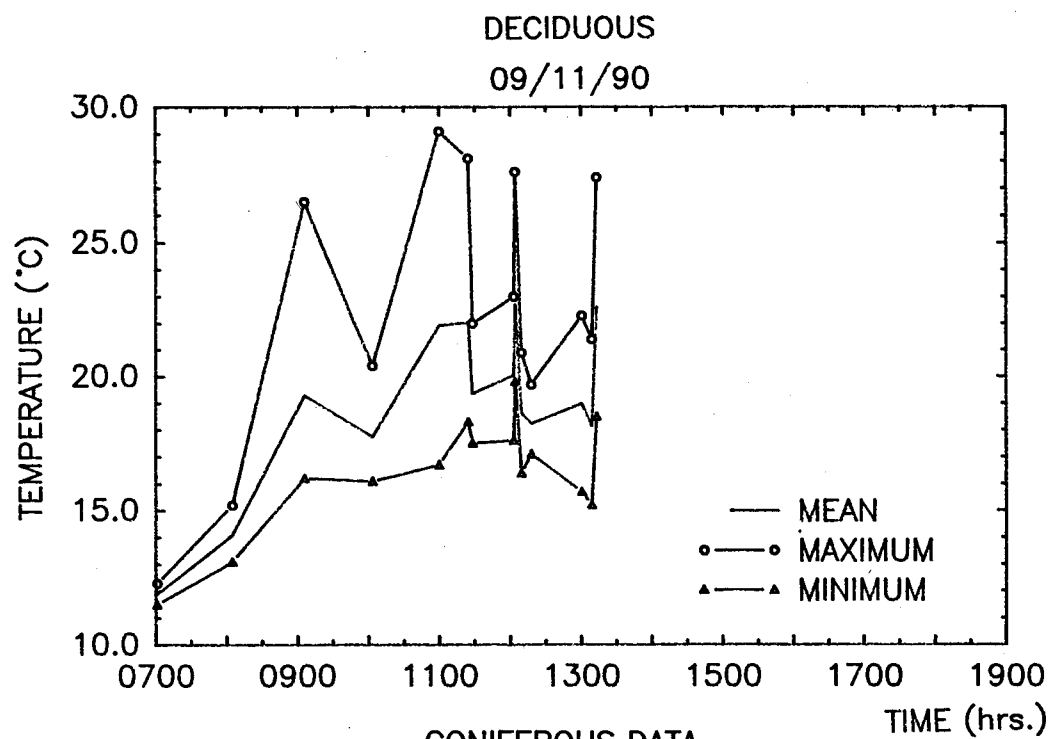


Figure 5.26: Descriptive Statistics for Deciduous and Coniferous Vegetation Shown Across Time for daytime period from 0700 hours through 1330 hours on 11 September, 1990.

5.1.8 Single, Isolated Tree Thermal Response

Videotapes of all thermal infrared imagery recorded at the KRC secondary site have been provided to Sparta, Inc., to support their individual tree thermal response study and modeling efforts, and also to the U.S. Army Communications and Electronics Command Center for Night Vision and Electro-Optics (C2NVEO). Copies of computer files of supporting meteorological and physical data, and of digitized thermal imagery have also been provided to Sparta, Inc.

Descriptive statistics for the apparent temperatures of the single tree trunk, leaf clusters, and for adjacent ground surfaces were generated using OS7 software (described in the section on scene metrics/enhancement of image processing capabilities, below.) These statistics and related data are detailed in the report contained in Appendix B.

5.2 Information data base

The Standard Scenes database was organized to make it compatible with modeling community needs, and was made available to the modeling community. The content and present format of data contained in the Standard Scenes database are described in Appendix C.

The experience gained from establishing the Standard Scenes database provides useful insights to help develop a database structure that will accommodate the large amount of information collected during measurement and characterization activity.

5.3 Modeling and simulation

5.3.1 Enhancement of Image Processing Capabilities

KRC has thermal digital image processing software to efficiently analyze calibrated thermal imagery. Based on the Silicon Graphics Model 3130 and 4D Series Graphics Workstations with UNIX system, the "OS7" software permits menu-driven processing of individual image frames, and database building from frame sequence statistics and image metric calculations. OS7 is written in FORTRAN, and contains no machine-specific commands nor proprietary subroutines from sources outside KRC; it is therefore a highly adaptable and easily portable program.

The OS7 menu features useful for analysis include image file selection, choice of a variety of input file format specifications, range and offset display selection, choice of 4 display scales (standard gray scale, inverted gray, green, and pseudo-color), and pixel interrogation. In addition, the menu provides for creation of rectangular or polygonal templates defining image sub-regions. Statistics are calculated for these sub-regions, and can be directed to an output disk file for storage.

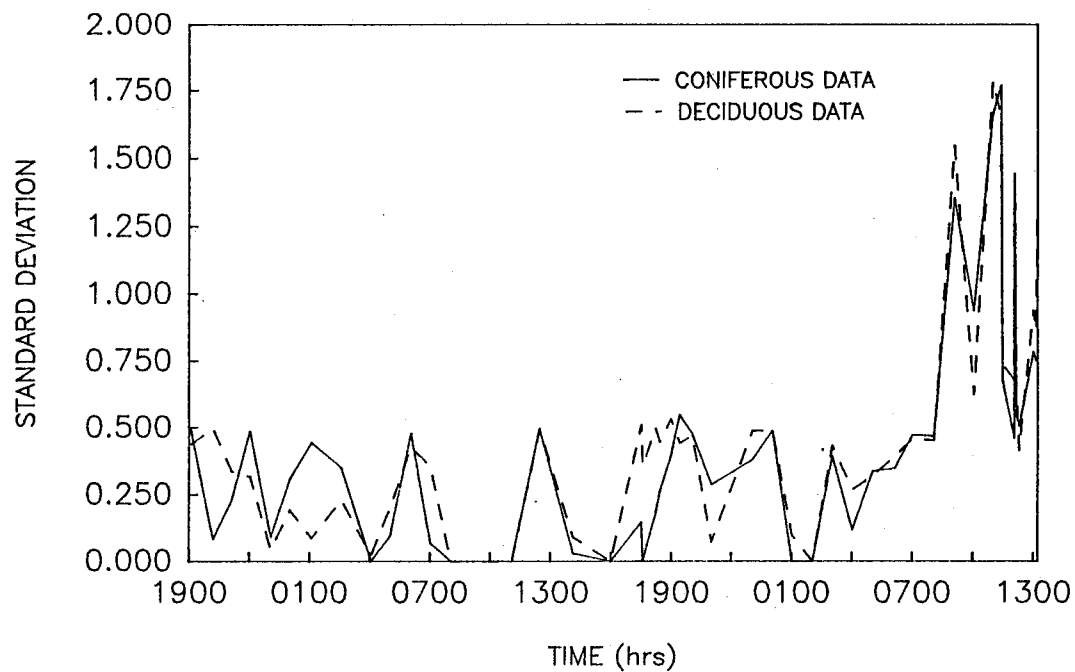


Figure 5.27: Standard Deviation for Deciduous vs. Coniferous Vegetation at Forest Edge.

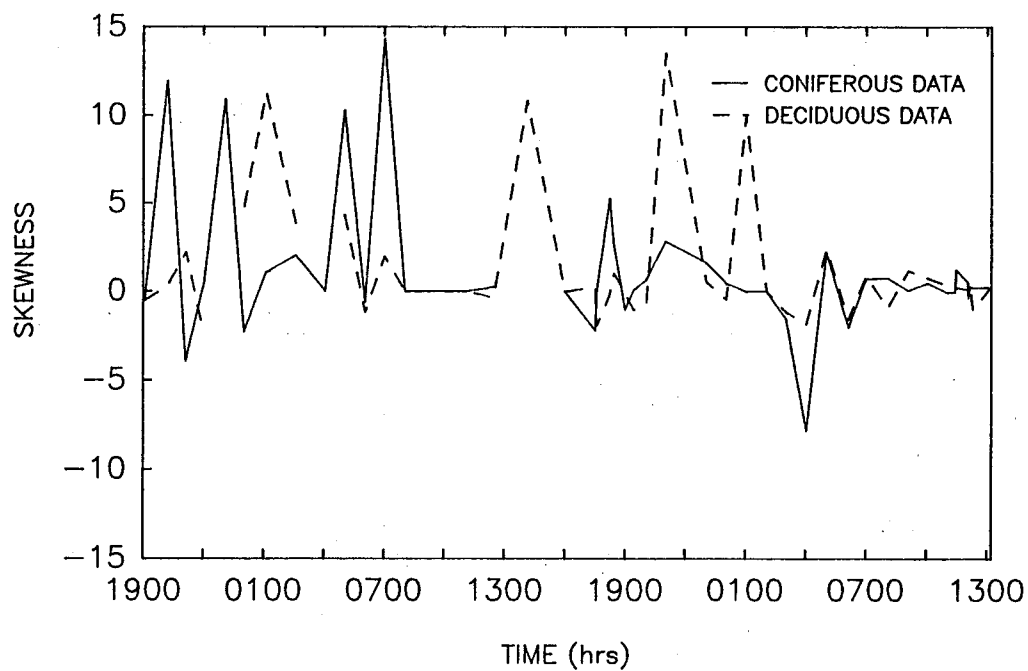


Figure 5.28: Second-Order Statistics for Deciduous vs. Coniferous Vegetation at Forest Edge: Skewness.

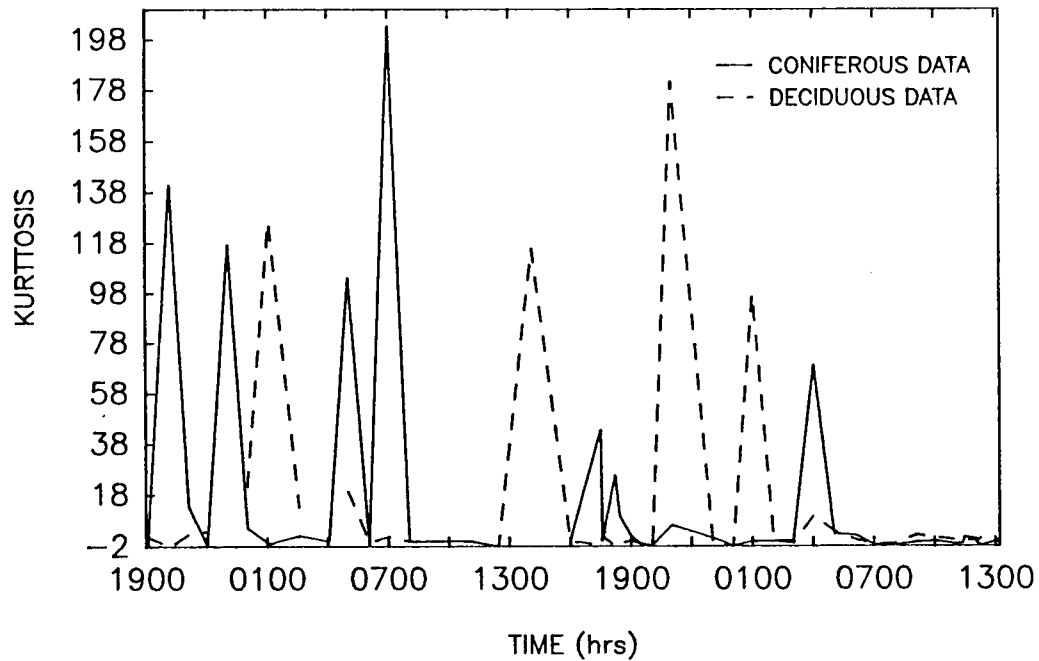


Figure 5.29: Second-Order Statistics for Deciduous vs. Coniferous Vegetation at Forest Edge: Kurtosis.

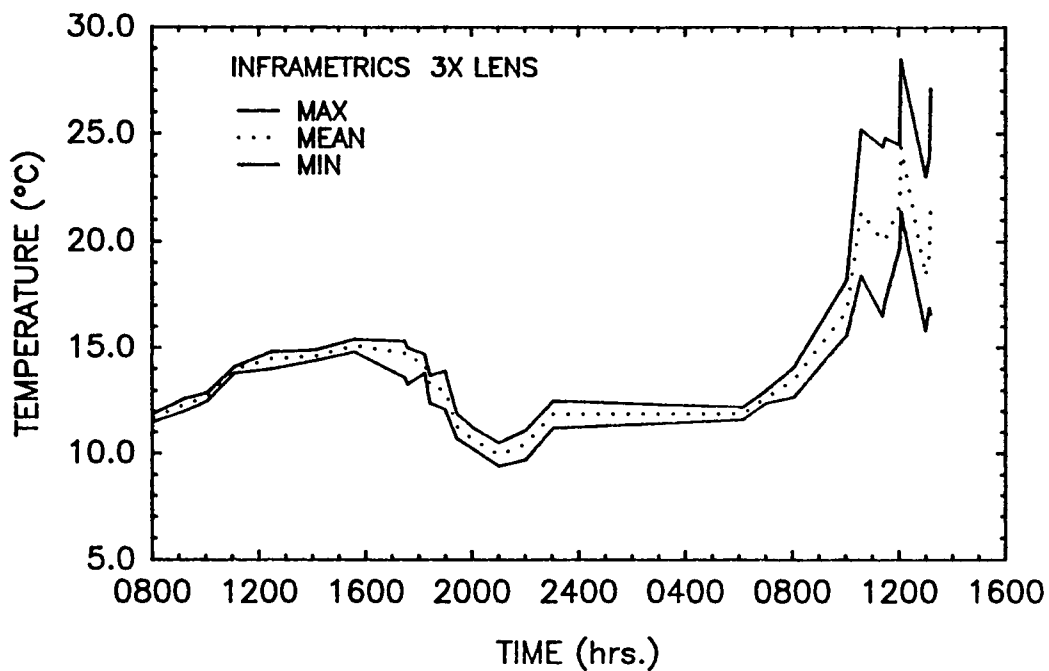


Figure 5.30: Maximum, Minimum, and Average Values of Apparent Temperature of Vegetation Along Forest Edge.

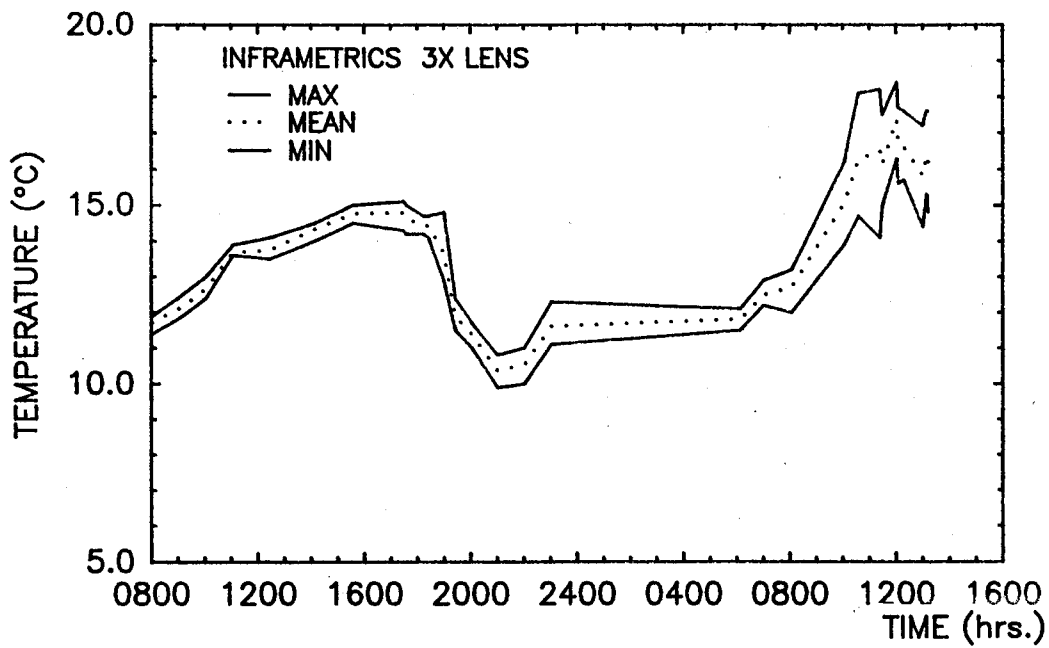


Figure 5.31: Maximum, Minimum, and Average Values of Apparent Temperature of Vegetation Within Forest Interior, in Gap Area.

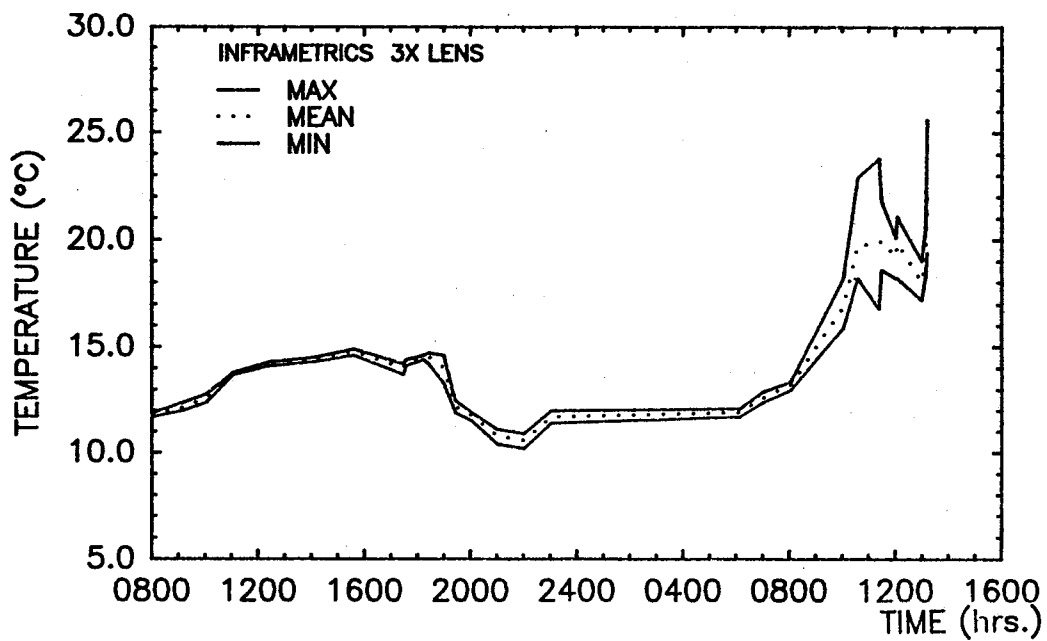


Figure 5.32: Maximum, Minimum, and Average Values of Apparent Temperature of Live Tree Trunk, in Gap Area.

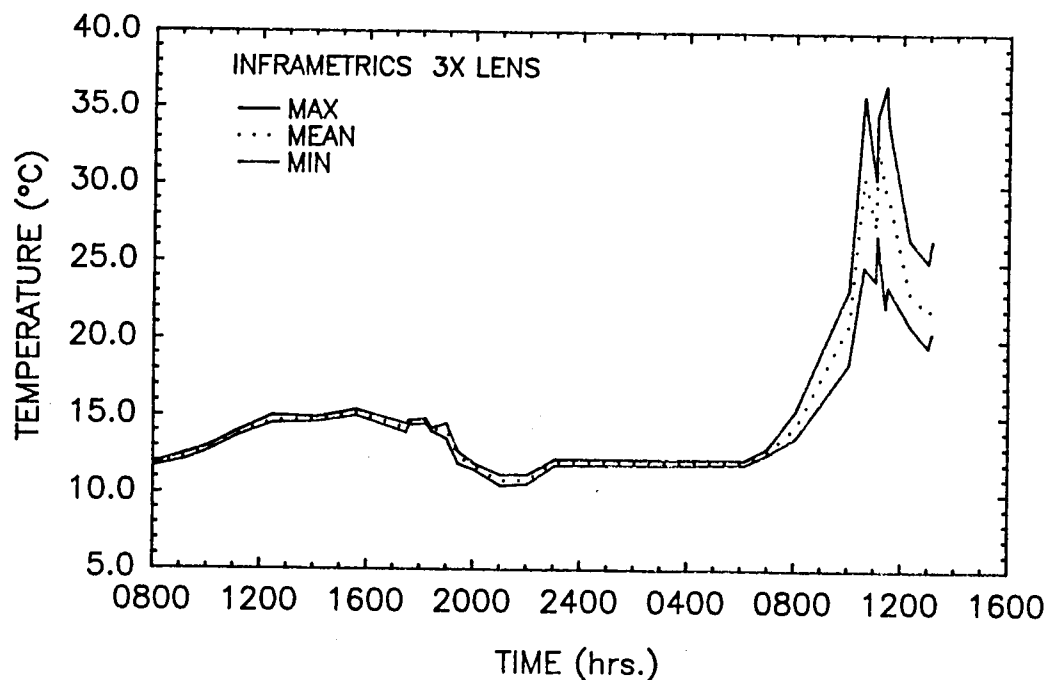


Figure 5.33: Maximum, Minimum, and Average Values of Apparent Temperature of Dead Tree Trunk, in Gap Area.

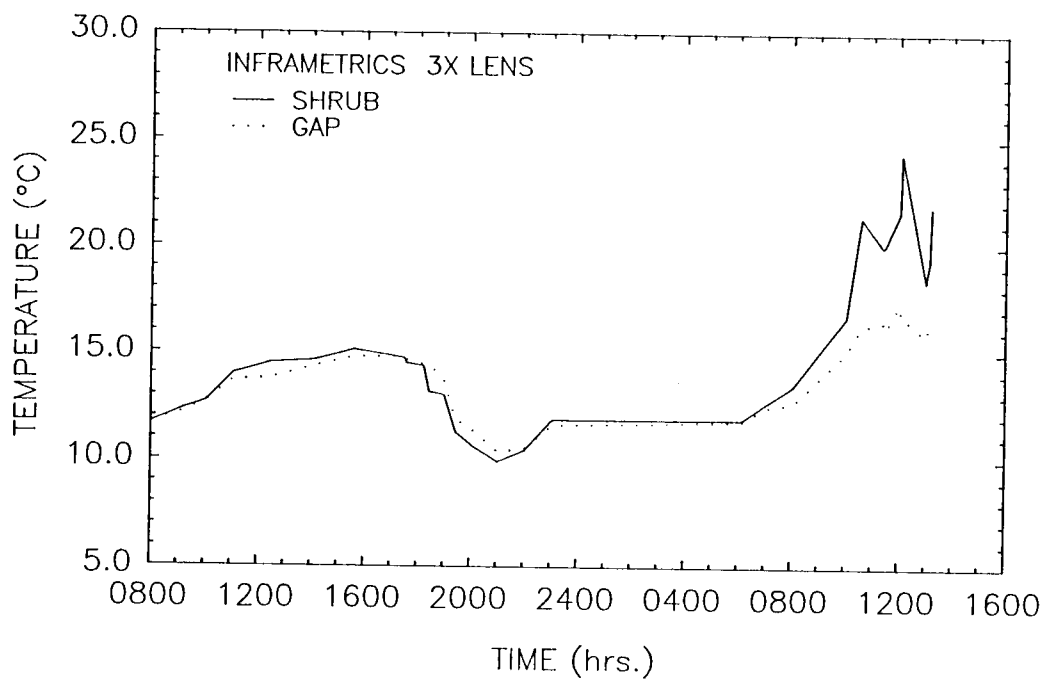


Figure 5.34: Comparison of Average Apparent Temperatures of Selected Scene Components, Across Time. Leafy subregions along forest edge ("SHRUB"), and within forest gap ("GAP").

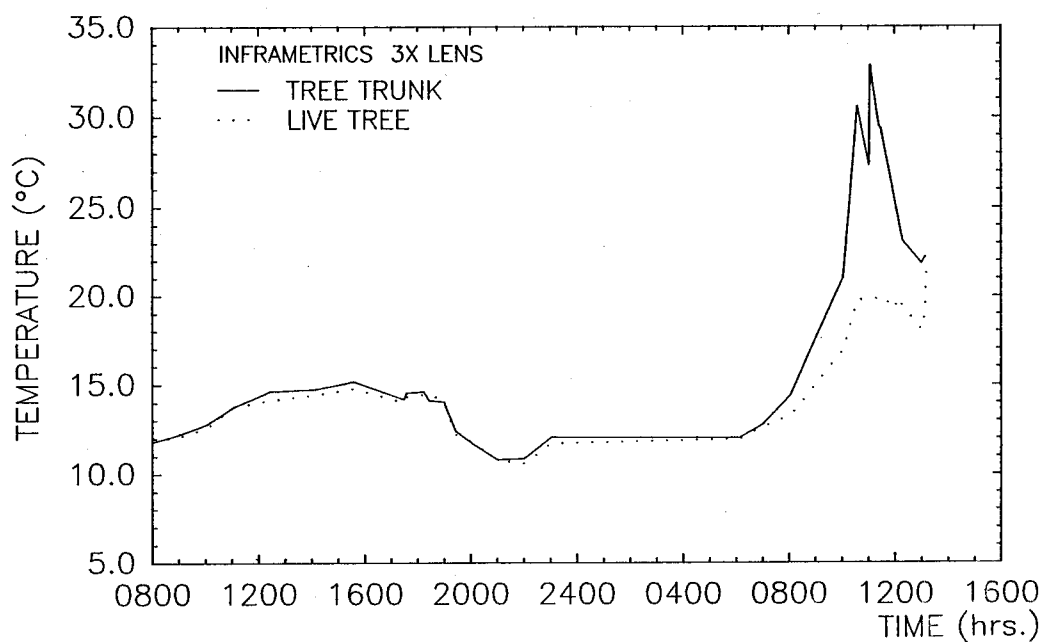


Figure 5.35: Comparison of Average Apparent Temperatures of Selected Scene Components, Across Time. Trunk of a live tree ("LIVE TREE"), and a standing dead tree ("TREE TRUNK").

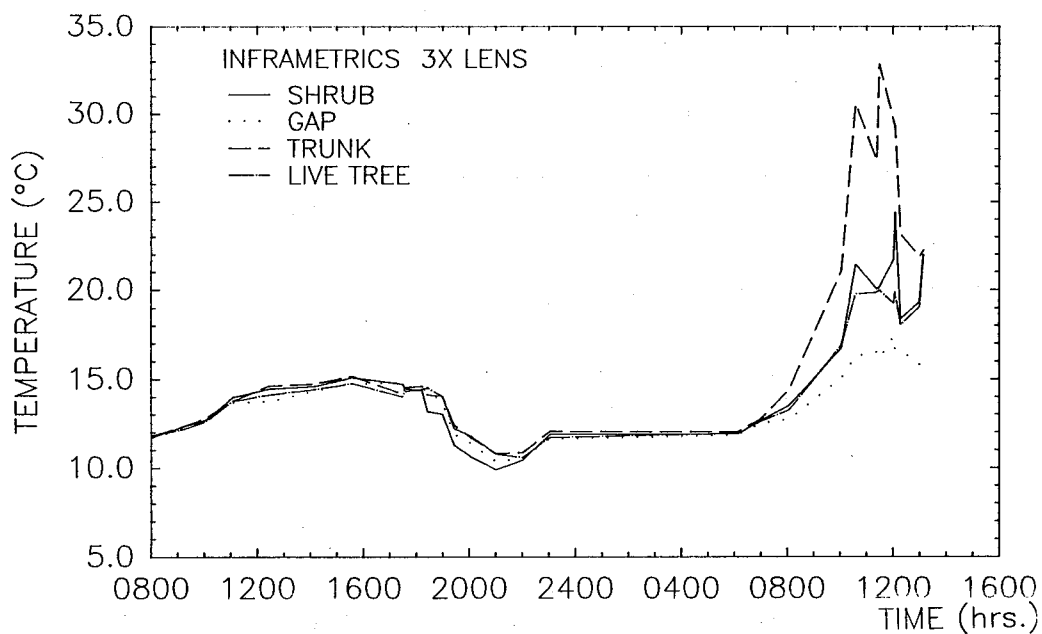


Figure 5.36: Comparison of Average Apparent Temperatures of Selected Scene Components, Across Time. Leafy subregions along forest edge ("SHRUB") and within forest gap ("GAP"), trunk of a live tree ("LIVE TREE"), and a standing dead tree ("TREE TRUNK").

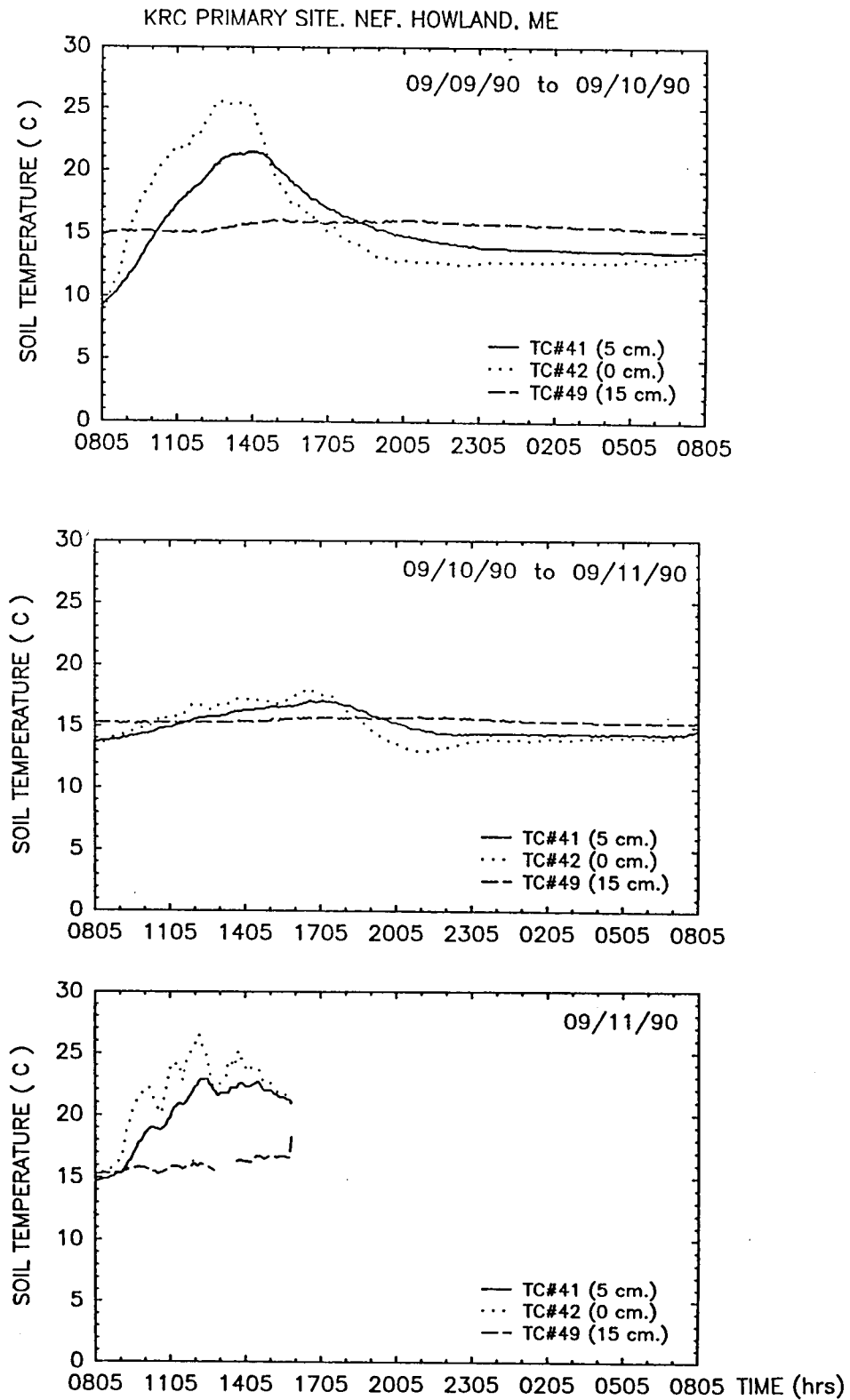


Figure 5.37: Soil Temperatures (°C) at 0, 5, and 15 cm, Location A.

KRC PRIMARY SITE, NEF, HOWLAND, ME

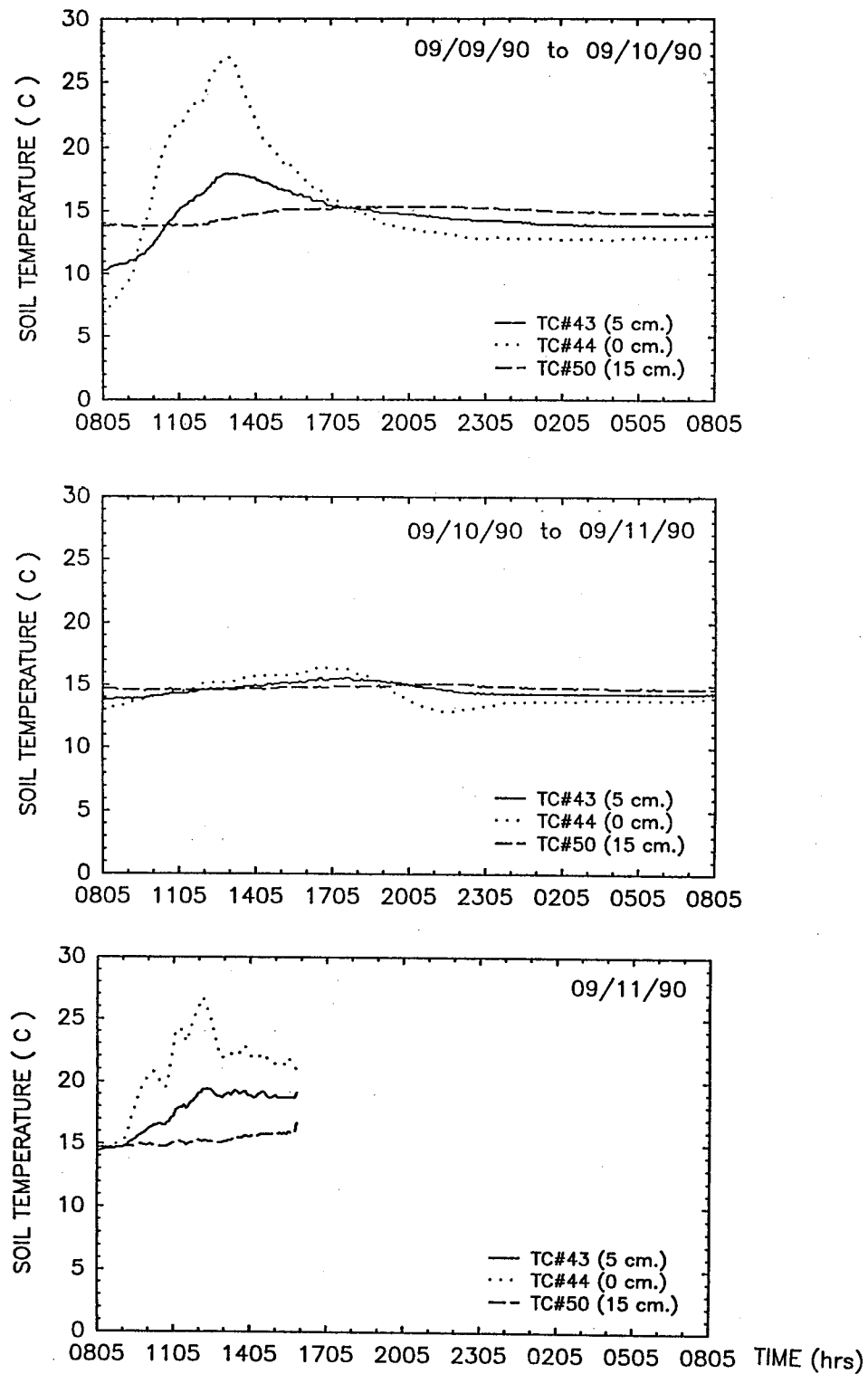


Figure 5.38: Soil Temperatures (°C) at 0, 5, and 15 cm, Location B.

KRC PRIMARY SITE, NEF, HOWLAND, ME

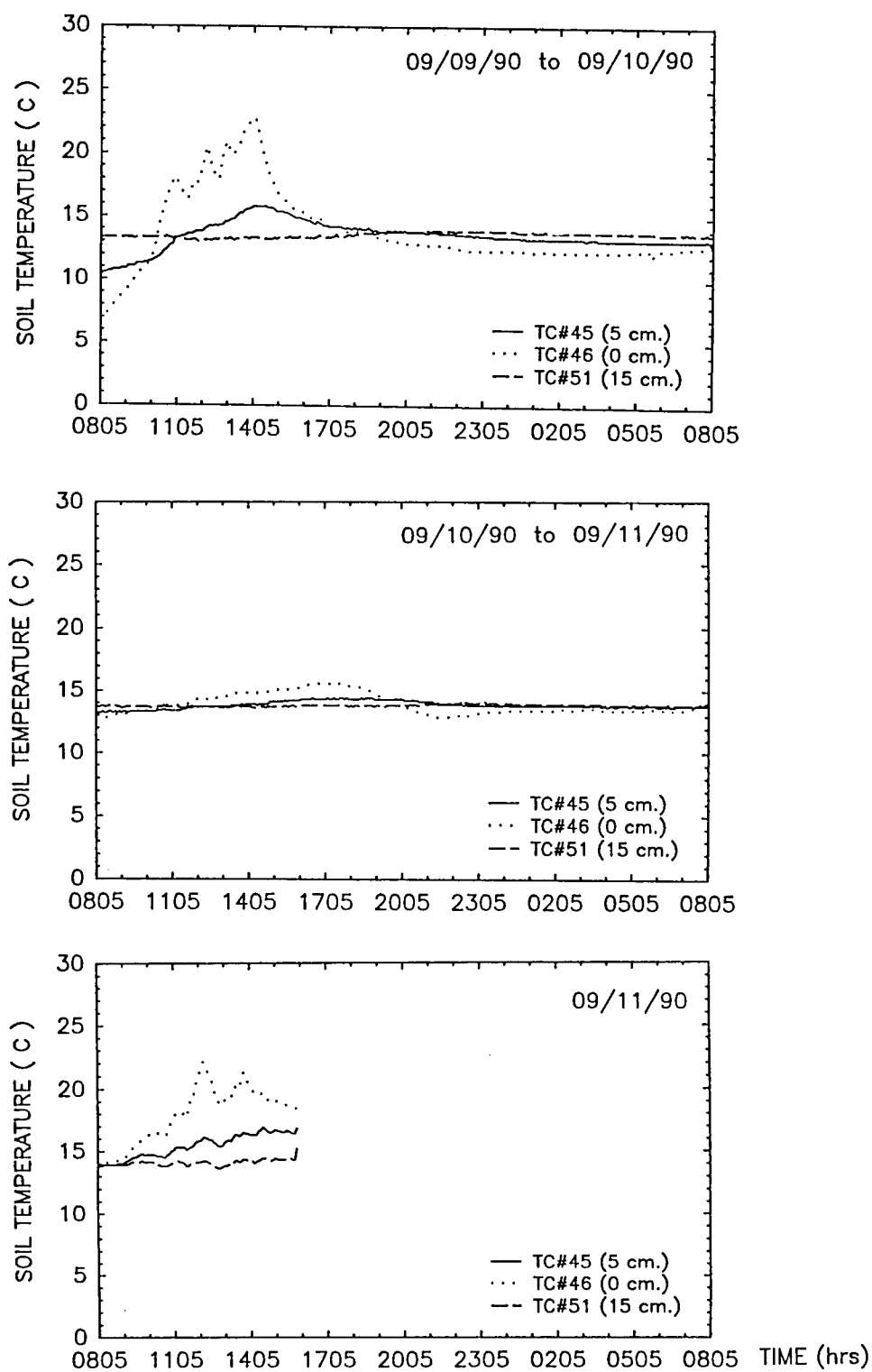


Figure 5.39: Soil Temperatures (°C) at 0, 5, and 15 cm, Location C.

KRC PRIMARY SITE, NEF, HOWLAND, ME

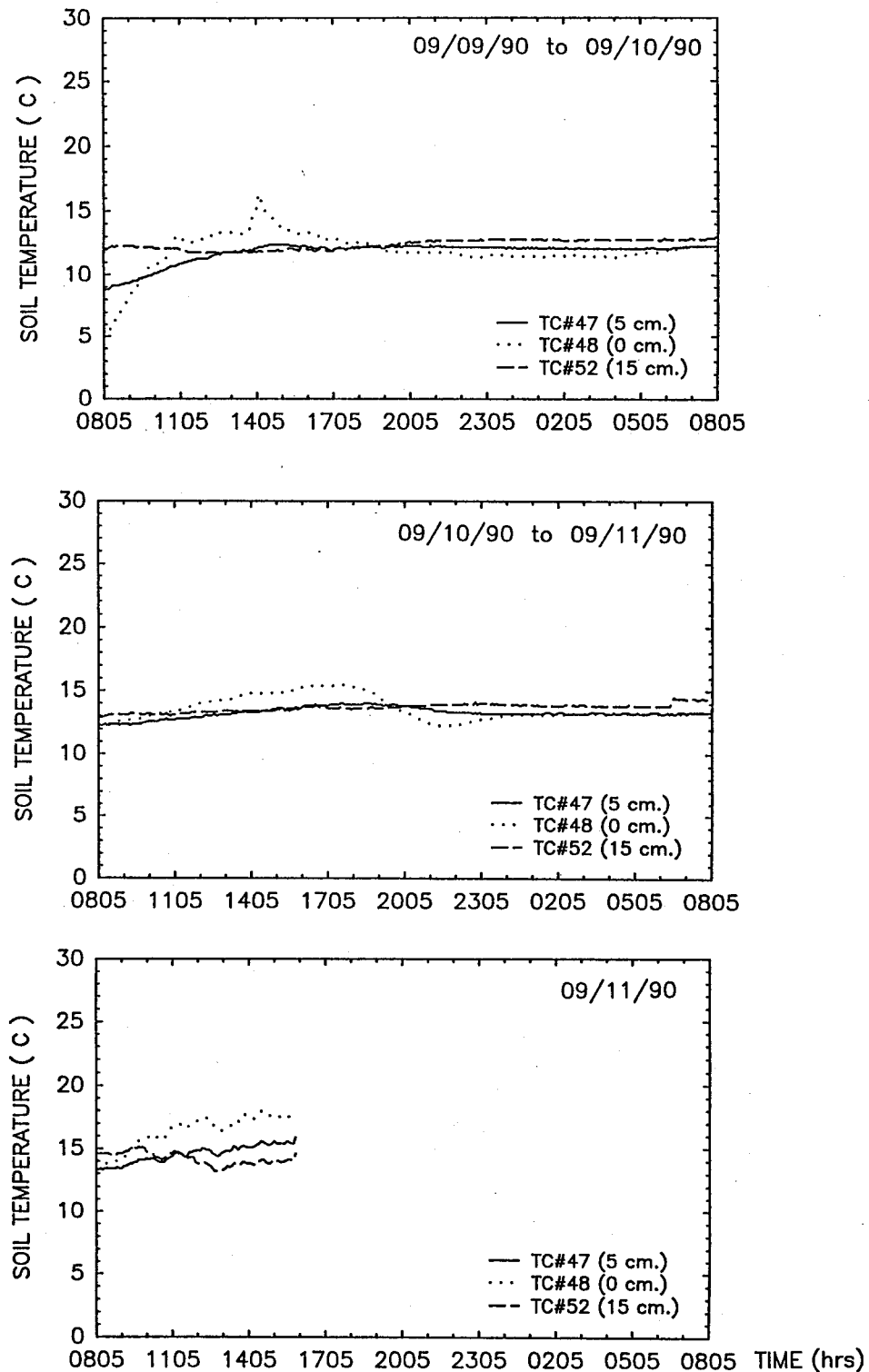


Figure 5.40: Soil Temperatures (°C) at 0, 5, and 15 cm, Location D.

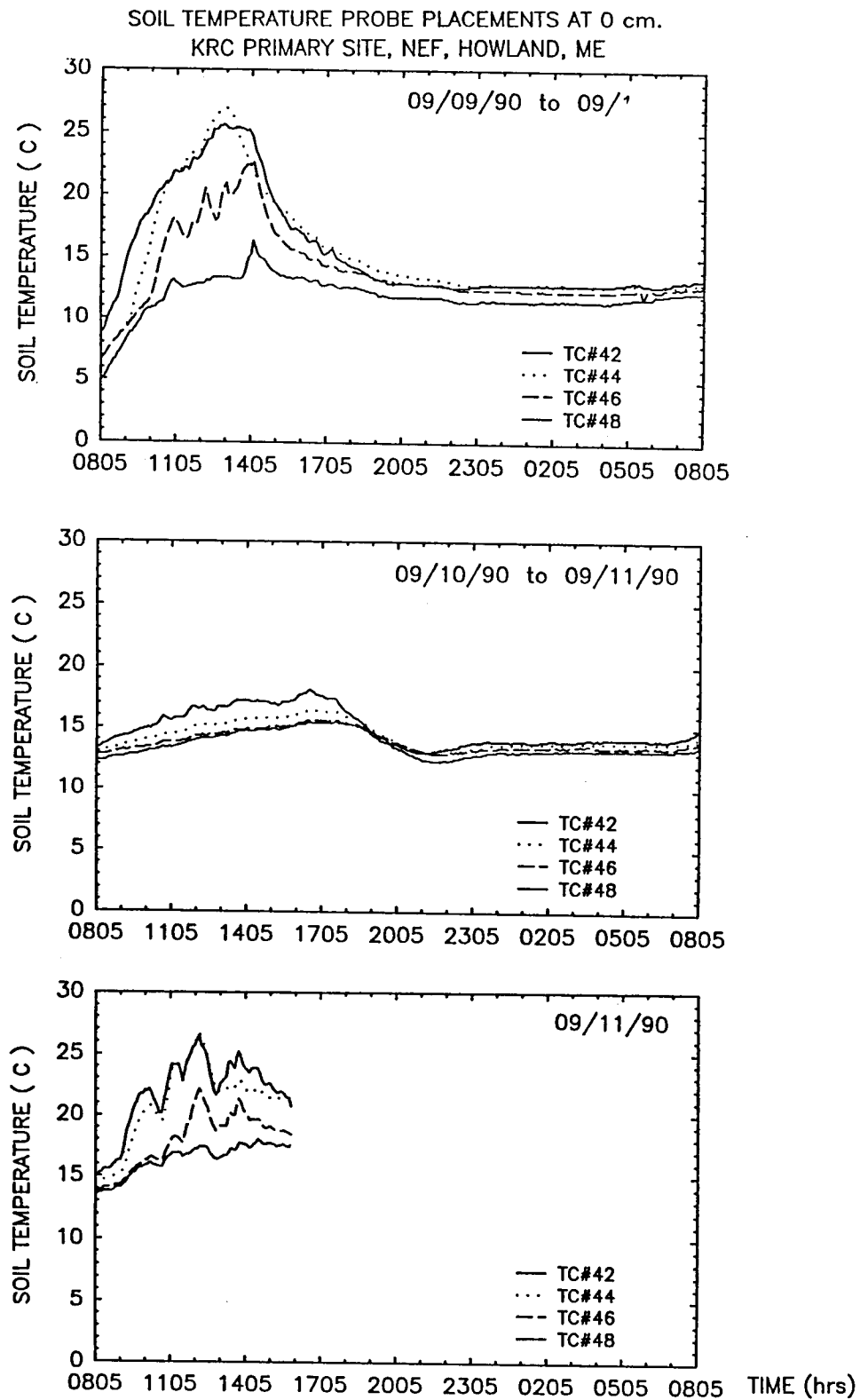


Figure 5.41: Soil Temperatures ($^{\circ}\text{C}$) at 0 cm (Surface) Across Soil Transect.

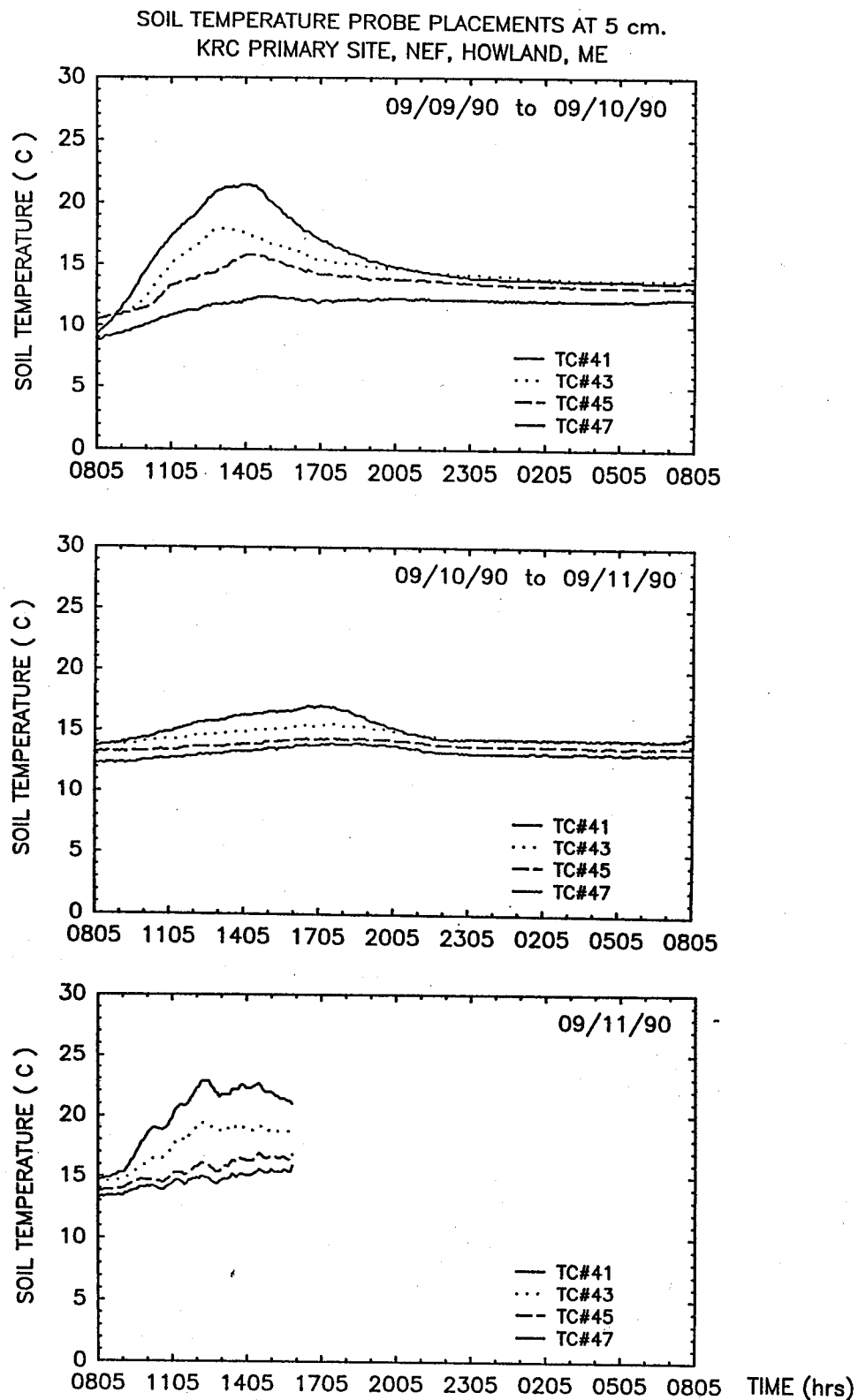


Figure 5.42: Soil Temperatures (°C) at 5 cm Depth, Across Soil Transect.

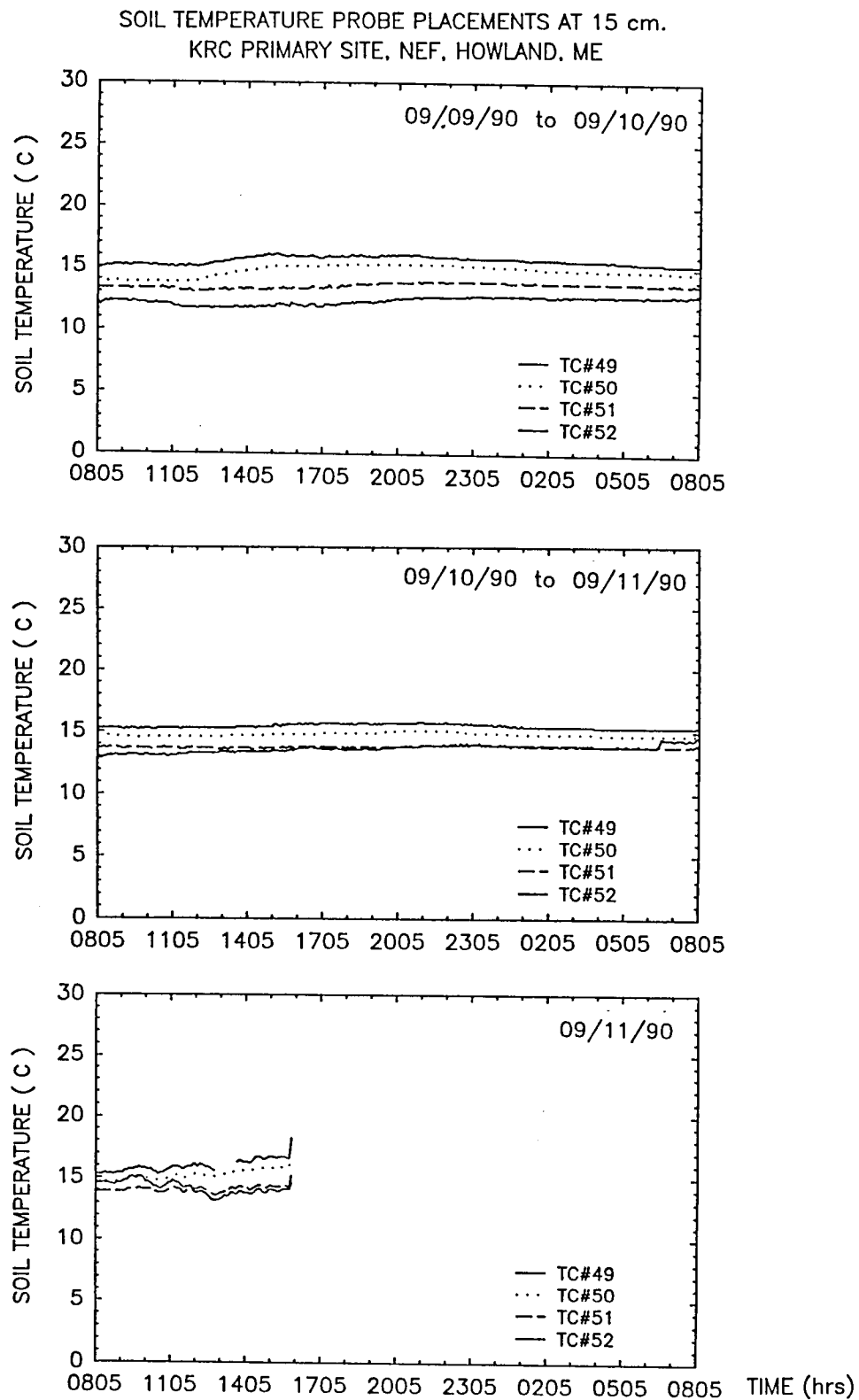


Figure 5.43: Soil Temperatures (°C) at 15 cm Depth, Across Soil Transect.

The menu has recently been augmented to include on-screen image processing capabilities: pixel averaging, on-screen frame reduction, on-screen mapping of pixel values from a gray scale (0-255) to a temperature scale specified by the user, and the option to save the reduced or temperature-converted version of the image frame to its own file. Figure 5.44 shows the OS7 menu display with this new feature, the image processing option, opened and ready for use.

The handling of image sub-regions has also been enhanced by the ability to store the individual pixel values in the sub-region to a separate file, and by an expanded repertoire of values that can be calculated for the sub-regions. These new capabilities include: pixel value histogramming, calculation of second-order statistics of skewness and kurtosis, one-dimensional autocorrelation length, and calculation of a scene clutter metric[6] for an image or image sub-region.

5.3.2 Scene Metrics

A Pascal program developed by Waterways Experiment Station WES, "SCENEMEZ" and a customized version titled "KRCMEZ", was applied to selected Standard Scenes imagery. This software was designed to calculate first and second order statistics for texture sub-regions of digitized imagery. Details of this software and its application to the Standard Scenes data are given in Appendix D.

A follow-up question from WES indicated that variance measures recorded for the Standard Scene imagery by the SCENEMEZ software seemed unusually high. Subsequently, output files of SCENEMEZ created at KRC were double-checked by comparing them both with the actual pixel values in the texture sub-regions, and also with statistics generated by KRC in-house (OS7) software. The results suggest that the version of SCENEMEZ tested by KRC is introducing default pixel values that cause variance-based calculations to be artificially high.

KRC's in-house software, OS7, was used to calculate descriptive statistics for a subset of the Standard Scenes database, the 24-hour sequence of thermal imagery for Standard Scene VI under late fall/early winter conditions. Figures on the following pages show results from OS7 computations that may be compared with those produced by SCENEMEZ. Table 5.3 lists statistical values for the image foreground of dried grasses, and Figures 5.45 through 5.48 graphically depict selected measures. Table 5.4 lists statistical values for the image treeline of bare, deciduous trees and brush, and Figures 5.49 through 5.52 graphically depict selected measures.

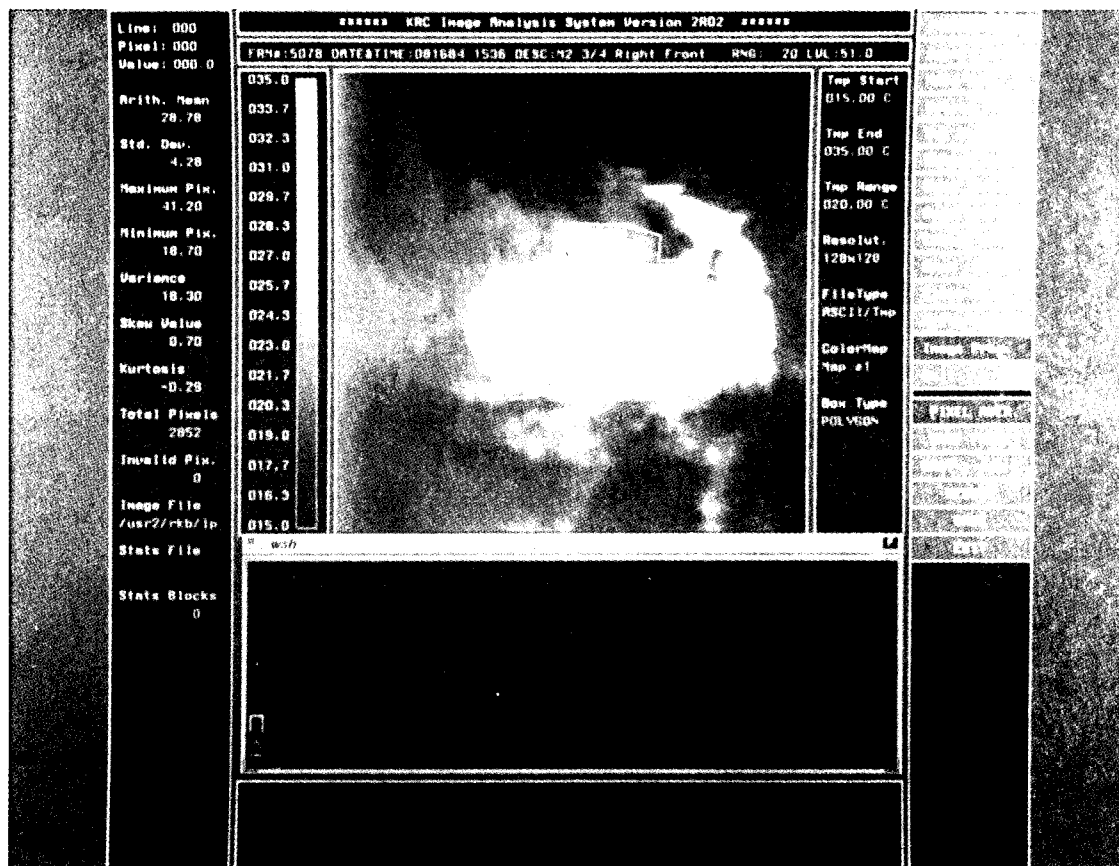


Figure 5.44: OS7 Menu Display with Image Processing Option Opened.

Table 5.3: Temperature Statistics for Standard Scene VI Foreground of Dried Grasses.

Values for 24-hour period during November, 1986. Calculated from long-wave infrared imagery using OS7 Software.

date	time	mean	std	min	max	vari	skew	kurt
110486	0600	-5.357	0.130	-5.000	-5.700	0.017	0.395	-0.141
110486	0700	-6.134	0.110	-5.700	-6.300	0.012	1.180	1.223
110486	0800	-7.350	0.096	-7.000	-7.500	0.009	0.567	0.161
110486	0900	-5.986	0.120	-5.600	-6.200	0.014	0.564	0.348
110486	1000	-4.019	0.187	-3.500	-4.400	0.035	0.018	-0.596
110486	1100	-2.630	0.244	-2.000	-3.200	0.060	0.113	-0.547
110486	1200	-1.678	0.663	-0.200	-3.100	0.439	-0.286	-0.738
110486	1300	-0.664	0.714	1.300	-2.400	0.510	-0.225	-0.378
110486	1400	2.277	0.603	3.500	0.900	0.363	0.133	-1.030
110486	1500	2.330	0.504	3.900	1.100	0.254	0.125	0.018
110486	1600	-0.596	0.428	0.700	-1.400	0.183	0.662	0.246
110486	1603	-1.180	0.484	0.000	-2.200	0.234	0.320	-0.510
110486	1700	-3.759	0.423	-2.400	-4.800	0.179	0.469	-0.151
110486	1800	-5.452	0.440	-4.300	-6.500	0.194	0.281	-0.613
110486	1900	-5.844	0.619	-3.300	-7.300	0.383	0.685	0.812
110486	2001	-4.872	0.433	-3.800	-6.300	0.188	-0.111	0.130
110486	2100	-5.996	0.456	-4.700	-7.200	0.208	0.142	0.448
110486	2200	-3.303	0.326	-2.300	-4.300	0.106	0.101	0.007
110486	2300	-5.297	0.366	-4.000	-6.300	0.134	0.006	0.513
110486	2400	-4.321	0.292	-3.400	-5.400	0.085	-0.182	0.106
110586	2459	-4.097	0.216	-3.600	-4.700	0.047	-0.220	-0.030
110586	2600	-3.506	0.251	-3.000	-4.300	0.063	-0.410	-0.182
110586	2700	-4.383	0.328	-3.200	-5.100	0.108	0.262	-0.159
110586	2759	-2.763	0.195	-2.300	-3.200	0.038	0.048	-0.723
110586	2900	-3.553	0.139	-3.000	-3.800	0.019	0.626	0.351
110586	3000	-1.334	0.157	-0.700	-1.700	0.025	0.755	1.061

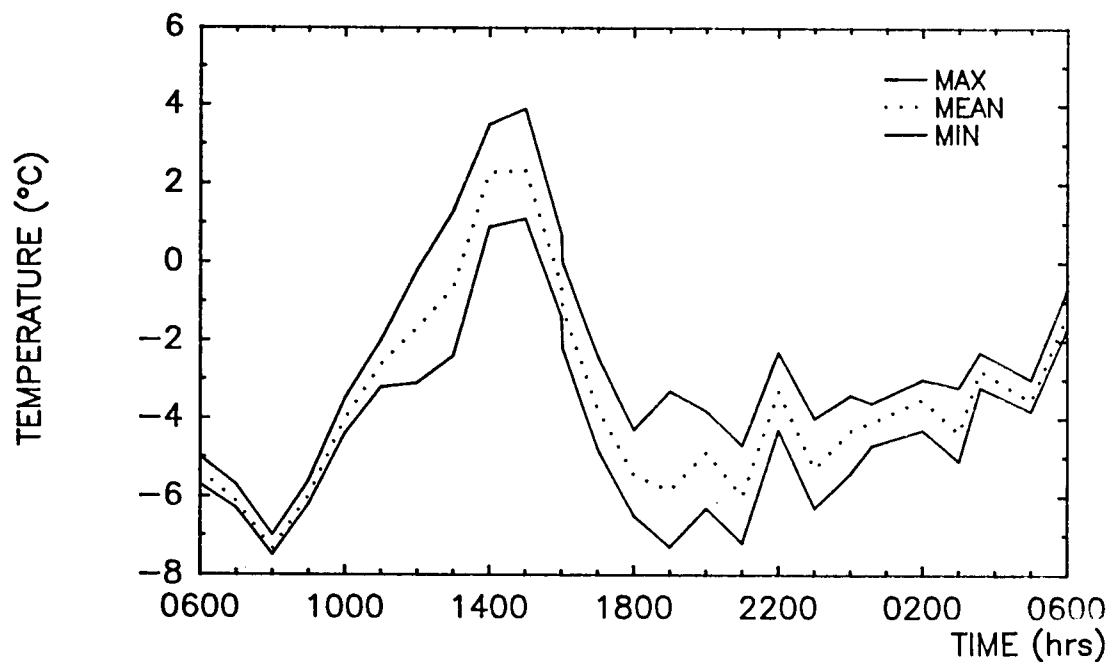


Figure 5.45: Average and Range, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.

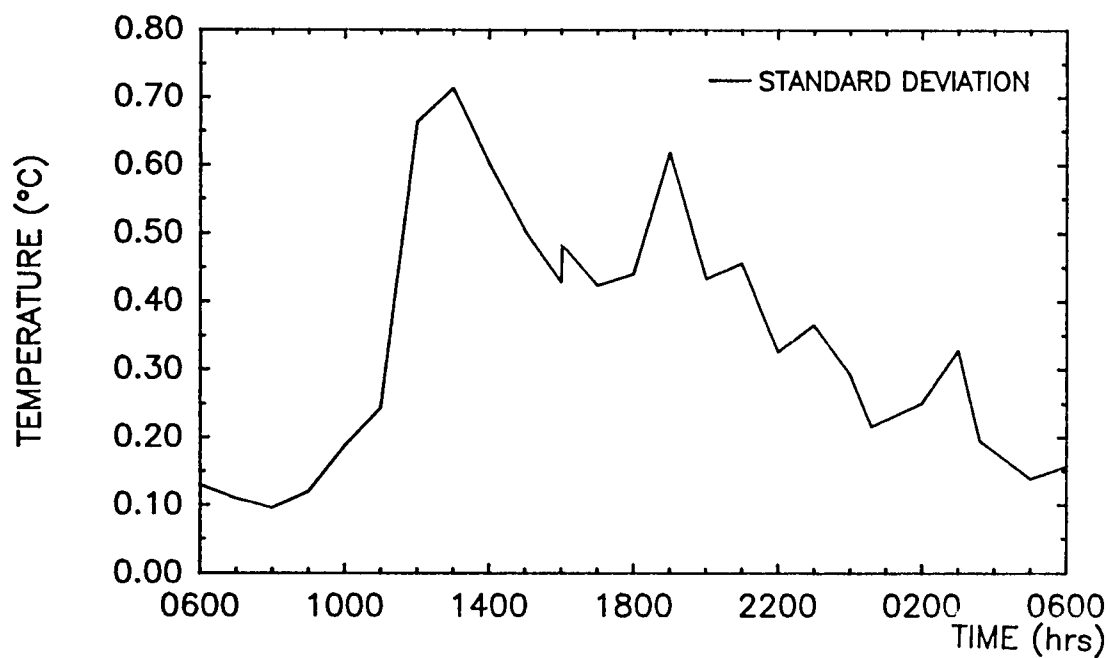


Figure 5.46: Standard Deviation, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.

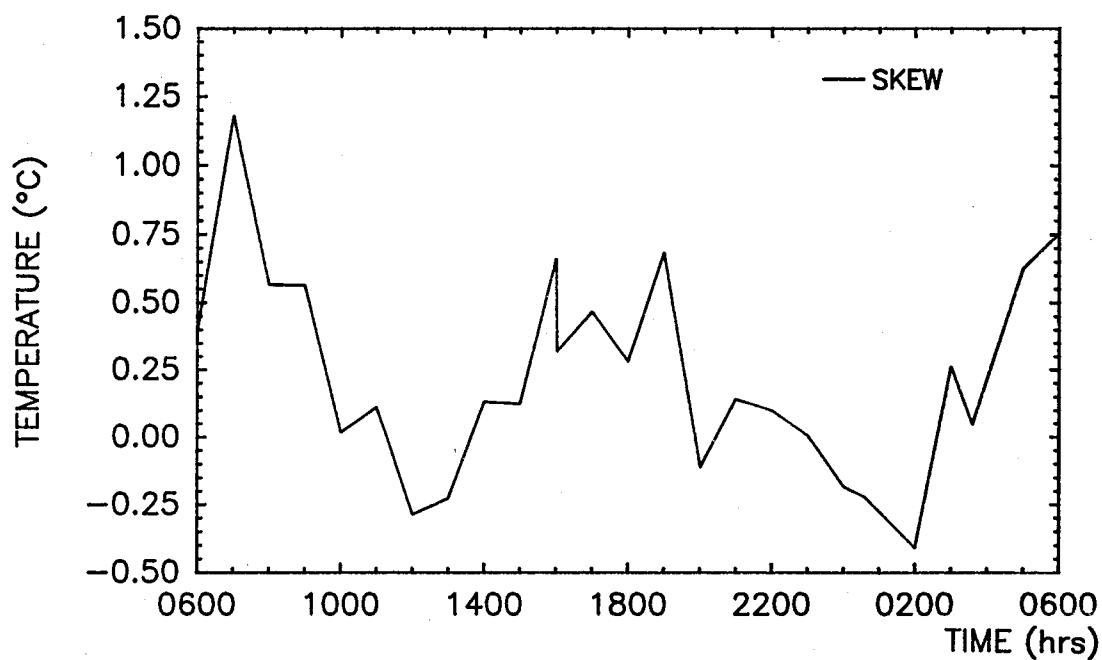


Figure 5.47: Skewness, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.

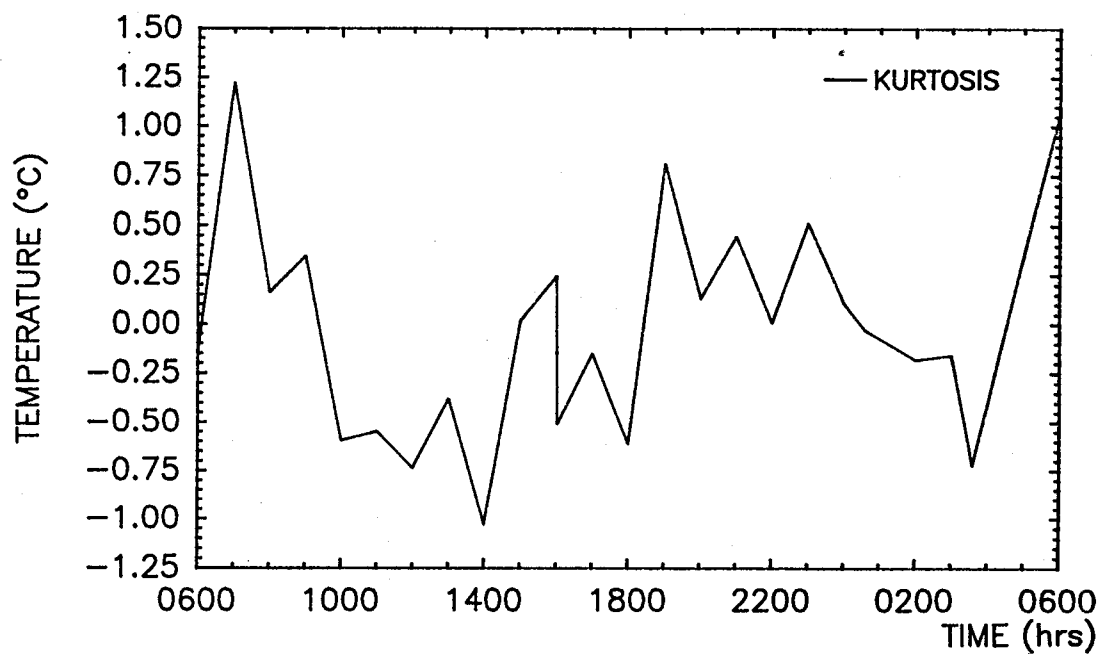


Figure 5.48: Kurtosis, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.

Table 5.4: Temperature Statistics for Standard Scene VI Treeline of Deciduous Trees.

For 24-hour period during November, 1986. Calculated from long-wave infrared imagery using OS7 Software.

date	time	mean	stdev	min	max	vari	skew	kurt
110486	0600	-4.846	0.221	-4.300	-5.500	0.049	0.032	-0.252
110486	0800	-7.112	0.146	-6.700	-7.400	0.021	0.492	-0.293
110486	0900	-5.996	0.125	-5.500	-6.200	0.016	0.719	0.500
110486	1000	-4.187	0.168	-3.500	-4.500	0.028	0.824	0.708
110486	1100	-3.055	0.158	-2.400	-3.400	0.025	0.917	1.410
110486	1200	-2.381	0.392	-0.100	-3.200	0.154	1.837	5.476
110486	1300	-1.565	0.388	0.300	-2.300	0.151	0.768	1.004
110486	1400	2.391	0.446	4.300	1.100	0.199	0.470	1.055
110486	1500	2.203	0.280	3.700	1.600	0.078	0.442	0.682
110486	1600	0.467	0.291	1.500	-0.200	0.085	0.311	0.089
110486	1603	0.090	0.326	0.900	-0.700	0.106	0.086	-0.738
110486	1700	-2.113	0.371	-1.000	-3.100	0.138	0.112	0.065
110486	1800	-3.702	0.502	-2.700	-5.200	0.252	-0.313	-0.396
110486	1900	-4.268	0.540	-3.000	-5.800	0.291	-0.003	-0.433
110486	2001	-3.615	0.375	-2.700	-4.800	0.140	-0.151	0.102
110486	2100	-4.385	0.442	-3.400	-5.700	0.196	-0.116	-0.175
110486	2200	-2.311	0.238	-1.600	-3.000	0.057	0.442	0.419
110486	2300	-4.260	0.296	-3.500	-5.100	0.087	0.406	-0.158
110486	0000	-3.467	0.258	-2.700	-4.300	0.066	0.147	0.136
110586	0059	-3.336	0.228	-2.700	-3.900	0.052	0.203	-0.136
110586	0200	-2.808	0.258	-2.200	-3.600	0.066	0.079	0.046
110586	0300	-3.584	0.285	-2.800	-4.400	0.081	0.318	0.233
110586	0359	-2.123	0.224	-1.500	-2.700	0.050	0.120	-0.406
110586	0500	-3.315	0.168	-2.800	-3.800	0.028	0.311	0.035
110586	0600	-1.221	0.170	-0.600	-1.600	0.029	0.620	0.413

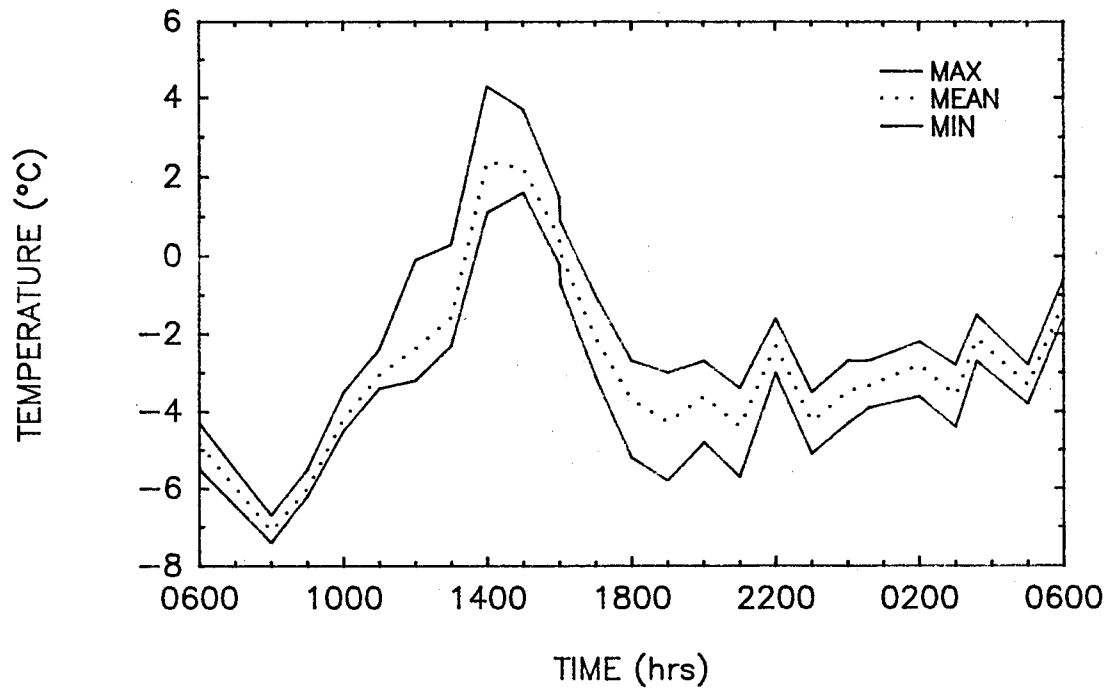


Figure 5.49: Average and Range, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.

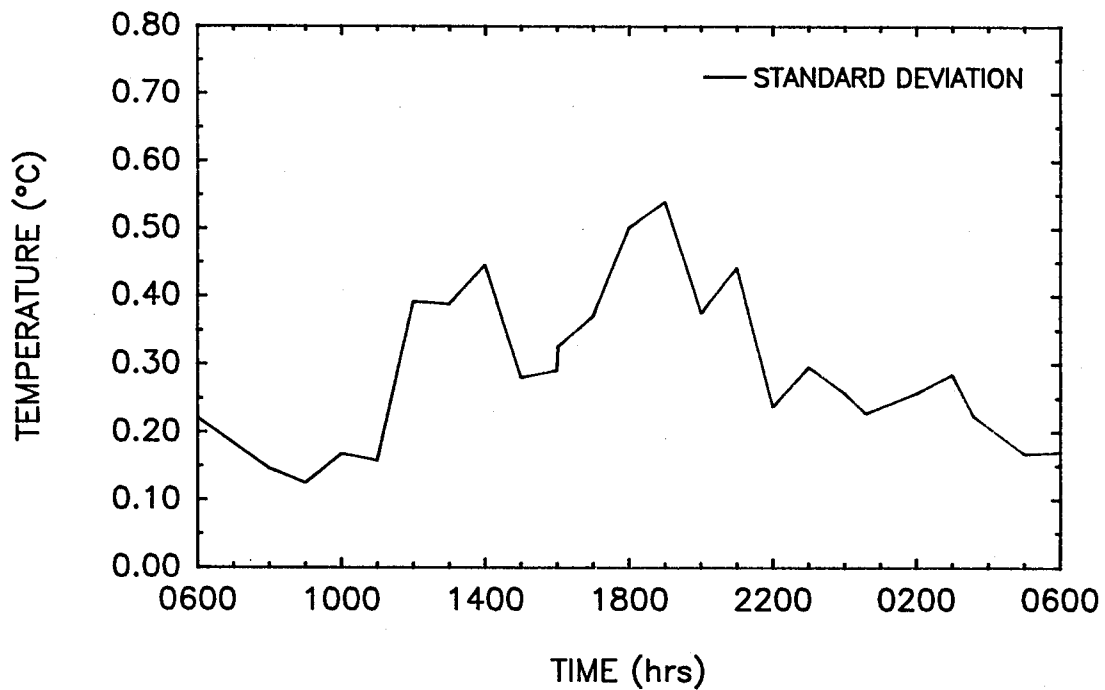


Figure 5.50: Standard Deviation, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.

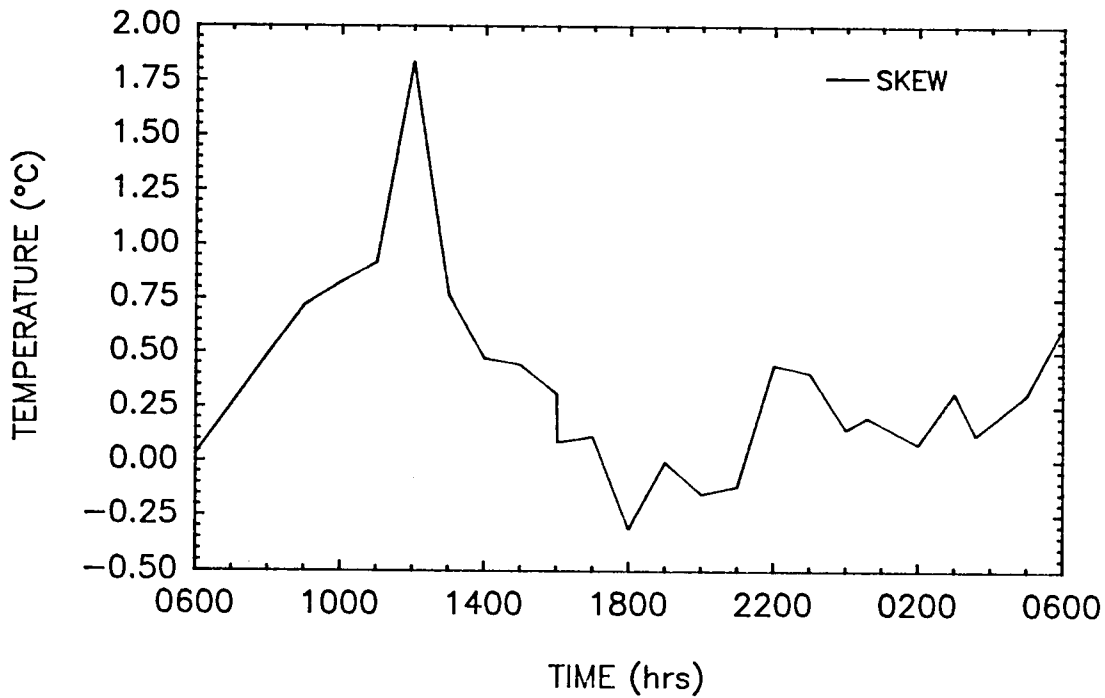


Figure 5.51: Skewness, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.

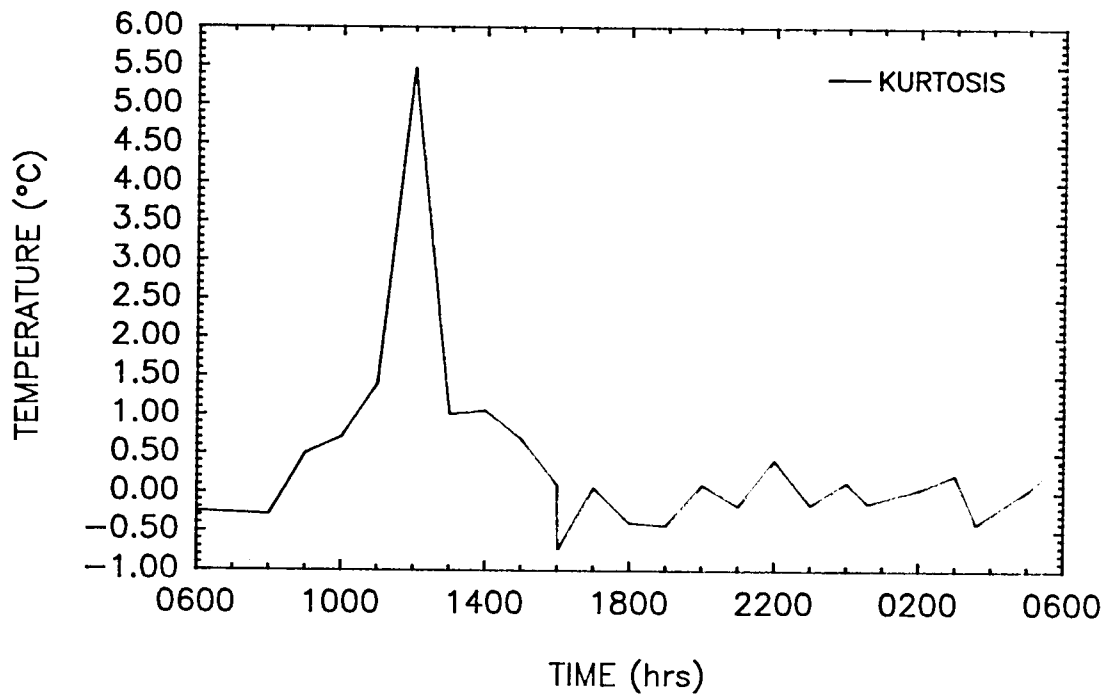


Figure 5.52: Kurtosis, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.

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A.1 Meteorological Data

Meteorological conditions during the FED MAC experiment were monitored at the KRC Primary site by means of a portable weather station comprised of an instrumentation tower, data acquisition loggers and pc-based automated data recording system operating on field power. Fifty-one channels of input data were recorded as part of this test; the data acquisition loggers are capable of monitoring up to 500 total analog and thermocouple inputs. Data on meteorological parameters particularly relevant to study of thermal infrared signatures were extracted and organized into computer files as described below.

A.1.1 Description of Data, Files and File Format

Each KRC meteorological data file includes observations for one test day. Files may be organized according to actual time of day (military clock), or by elapsed time, as shown in the file excerpts in Tables A.1 and A.2. Each file has a two-line header that identifies the date, start time, and test site at which the data was collected.

Files organized by time of day include "W090990.DAT" which contains observations beginning at 0805 hours on 09/09/90, and "W091090.DAT" which has data beginning at 0720 hours on 09/10/90 (and continuing to the end of the test on 09/11/90). The format of these files is:

TIME, AIRT(EDGE), AIRT(OPN), SOLAR, WINDSPD, HUMID, LWIR, WINDIR
FORMAT(I4,7F9.3)

where:

TIME	Time of day (0000 to 2400 hours)
AIRT(EDGE)	Air Temperature (°C) at edge of forest
AIRT(OPN)	Air Temperature (°C) in open field
SOLAR	Solar Irradiance (W/M^2)
WINDSPD	Wind Speed (M/sec)
HUMID	Relative Humidity (%)
LWIR	Longwave Infrared Radiation
WINDIR	Wind Direction (0 - 360°)

Files organized by elapsed time include "ELPT0909.DAT" which contains observations beginning at 0805 hours on 09/09/90, and "ELPT0910.DAT" which has data beginning at 0720 hours on 09/10/90 (and continuing to the end of the test on 09/11/90). The format of these files is:

TIMELAPSE, AIRT(EDGE), AIRT(OPN), SOLAR, WINDSPD, HUMID, LWIR,
WINDIR
FORMAT(F8.3,1X,7F9.3)

where all variables are the same as listed above, with the exception of TIMELAPSE, which is elapsed time in hours.

A.1.2 Data Plots

Figures on the following pages graphically depict the data for six significant meteorological parameters recorded at the KRC primary site during the FED MAC 1990 experiment. These are environmental variables that either have a direct influence on the thermal signature of exposed surfaces, or affect heat transfer processes on those surfaces. Ambient air Temperature ($^{\circ}\text{C}$) at edge of forest and in the open field are shown in Figure A.1. Solar irradiance (W/M^2) is shown in Figure A.2, and longwave infrared radiation in A.3 Figure A.4 depicts relative humidity (%). Figures A.5 and A.6 show wind speed (M/sec) and wind direction ($0 - 360^{\circ}$ clockwise from north), respectively.

A.2 Soil Temperature Profile from Meteorological Station Data

A.2.1 Description of Data, Files and File Format

Information on soil temperature was collected from the large probe set next to the weather tower. Readings were automatically recorded at five minute intervals by the meteorological station computer. As shown in the file excerpt in Table A.3, the file has a two-line header that identifies the file type, date, and test site at which the data was collected.

Files "ST090990.ME" and "ST091090.ME" contain data from the main weather tower soil probe, for 09 September, and 10-11 September, respectively. The format of these files is:

TIME, T00CM, T01CM, T05CM, T10CM, T20CM, T50CM

FORMAT(I4,6F9.3)

where:

TIME	Time of day (0000 to 2400 hours)
T00CM	Soil Temperature ($^{\circ}\text{C}$) at the surface (0 cm. depth)
T01CM	Soil Temperature ($^{\circ}\text{C}$) at 1 cm. depth
T05CM	Soil Temperature ($^{\circ}\text{C}$) at 5 cm. depth
T10CM	Soil Temperature ($^{\circ}\text{C}$) at 10 cm. depth
T20CM	Soil Temperature ($^{\circ}\text{C}$) at 20 cm. depth
T50CM	Soil Temperature ($^{\circ}\text{C}$) at 50 cm. depth

Table A.1: Meteorological data file organized by time
Excerpt of file "08050909.DAT" showing 2-line header and data.

KRC Met Data: 09/09/90. Start time: 0805. Site: FED MAC. Howland, ME.							
TIME	AIRT(EDGE)	AIRT(OPN)	SOLAR	WINDSPD	HUMID	LWIR	WINDDIR
0805	6.100	5.800	258.376	0.235	98.941	323.044	231.894
0810	6.500	6.400	266.691	1.888	98.735	323.044	201.276
0815	7.200	7.100	274.882	1.382	98.571	324.186	204.174
0820	7.600	7.500	290.642	1.213	98.988	322.588	185.922
0825	7.700	7.700	309.754	1.368	98.694	320.990	185.922
0830	8.100	8.100	322.412	1.223	98.229	320.077	192.618
0835	-999.000	8.700	336.807	1.193	98.024	318.022	177.012
0840	9.700	8.900	351.451	1.734	95.884	317.109	170.586
0845	10.300	9.700	356.043	0.942	94.694	318.478	169.524
0850	10.900	10.200	358.525	1.068	91.562	314.826	207.180
0855	11.700	10.800	374.286	1.247	89.661	312.771	193.320
0900	12.600	11.300	386.075	0.563	85.976	310.716	176.400
0905	12.900	11.800	417.472	1.045	83.910	310.945	198.936

Table A.2: Meteorological data file organized by elapsed time
Excerpt of file "0909ELPT.DAT" showing 2-line header and data.

KRC Met Data: 09/09/90. Elapsed time start: 0805. Site: FED MAC. ME							
TIMELAPSE	AIRT(EDGE)	AIRT(OPN)	SLOAR	WINDSPD	HUMID	LWIR	WINDDIR
0.000	6.100	5.800	258.376	0.235	98.941	323.044	231.894
0.083	6.500	6.400	266.691	1.888	98.735	323.044	201.276
0.167	7.200	7.100	274.882	1.382	98.571	324.186	204.174
0.250	7.600	7.500	290.642	1.213	98.988	322.588	185.922
0.333	7.700	7.700	309.754	1.368	98.694	320.990	185.922
0.417	8.100	8.100	322.412	1.223	98.229	320.077	192.618
0.500	-----	8.700	336.807	1.193	98.024	318.022	177.012
0.583	9.700	8.900	351.451	1.734	95.884	317.109	170.586
0.667	10.300	9.700	356.043	0.942	94.694	318.478	169.524
0.750	10.900	10.200	358.525	1.068	91.562	314.826	207.180
0.833	11.700	10.800	374.286	1.247	89.661	312.771	193.320
0.917	12.600	11.300	386.075	0.563	85.976	310.716	176.400
1.000	12.900	11.800	417.472	1.045	83.910	310.945	198.936

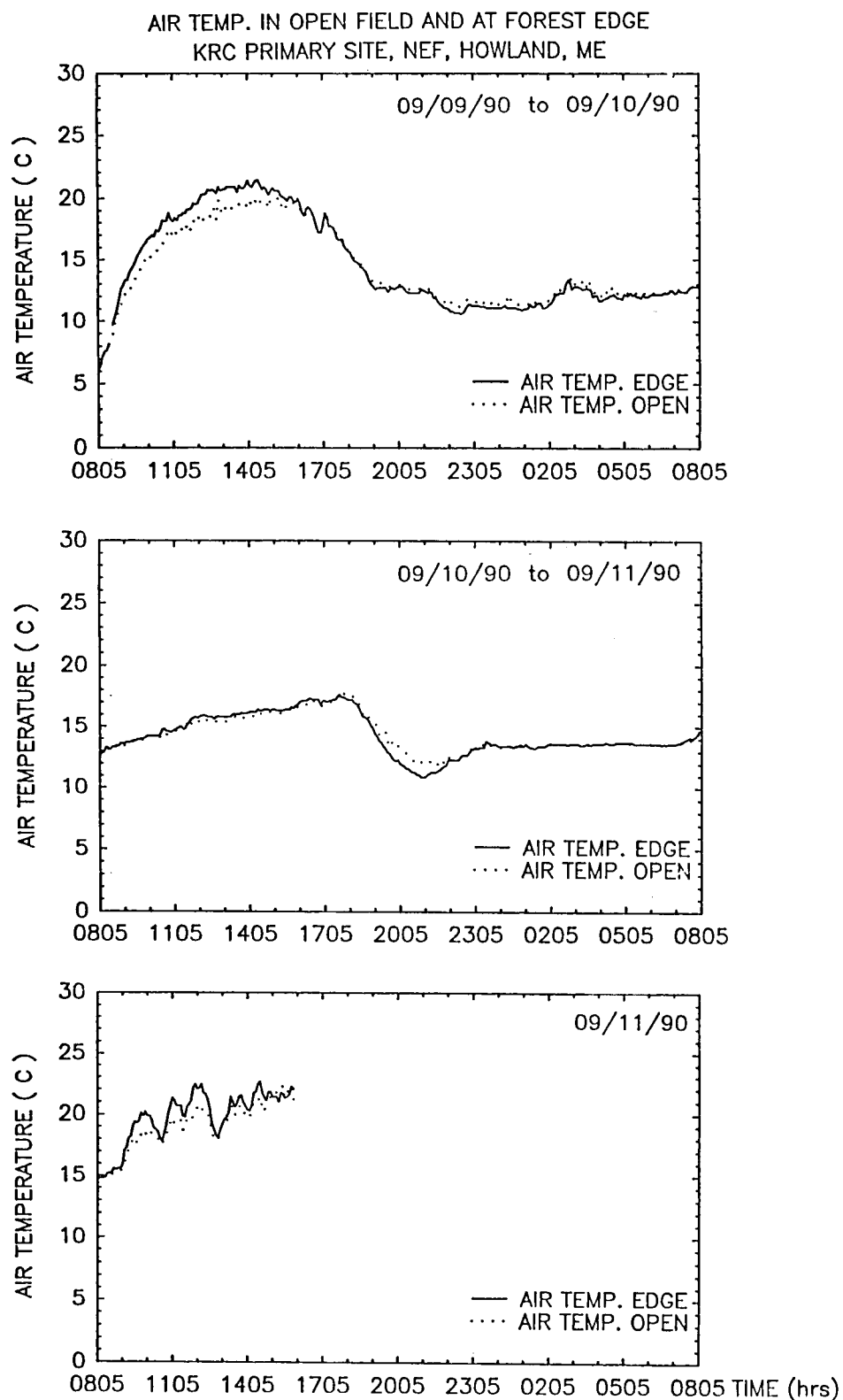


Figure A.1: Air Temperatures (°C) in Open Field and at Forest Edge
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

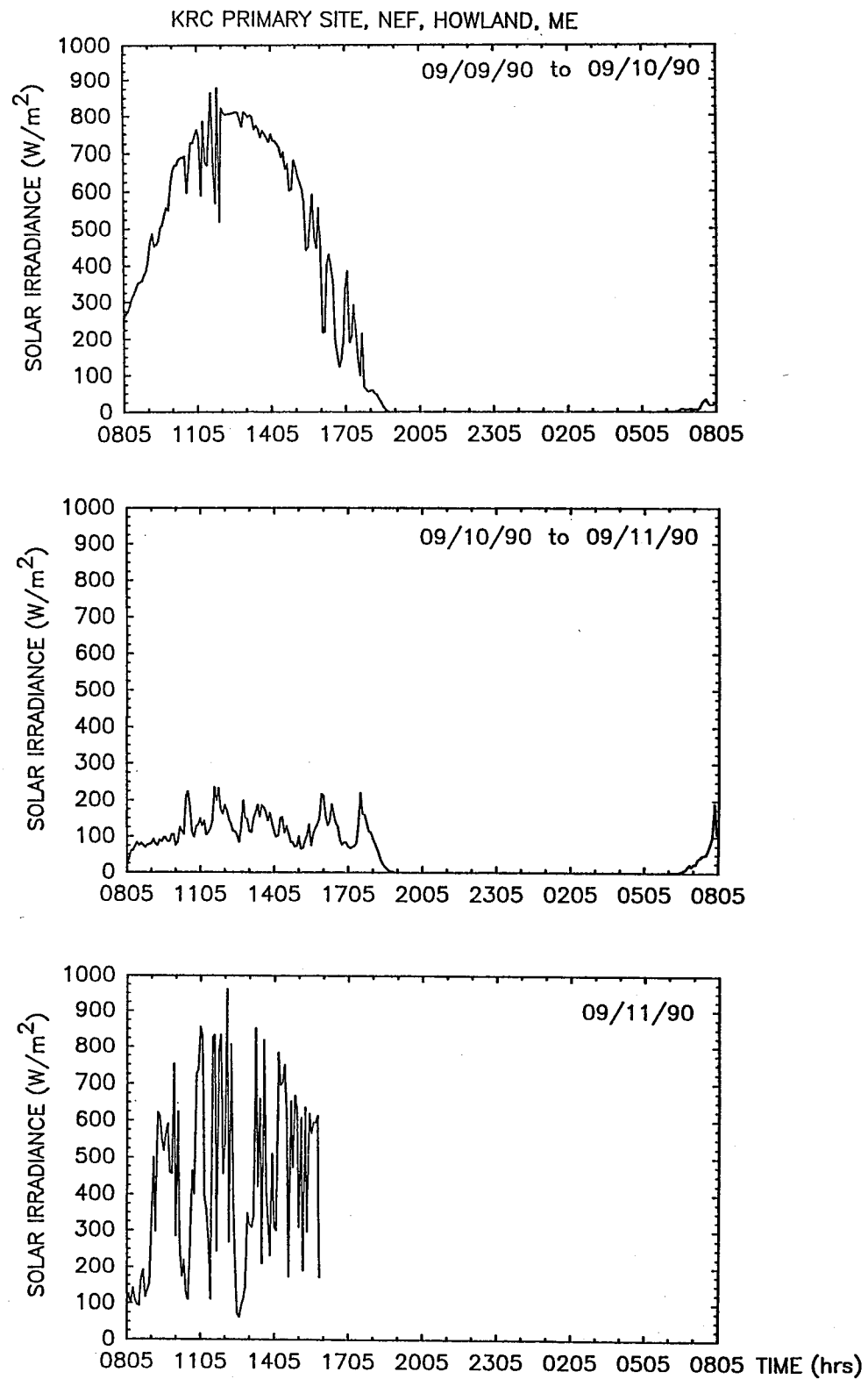


Figure A.2: Solar Irradiance (W/m^2)
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

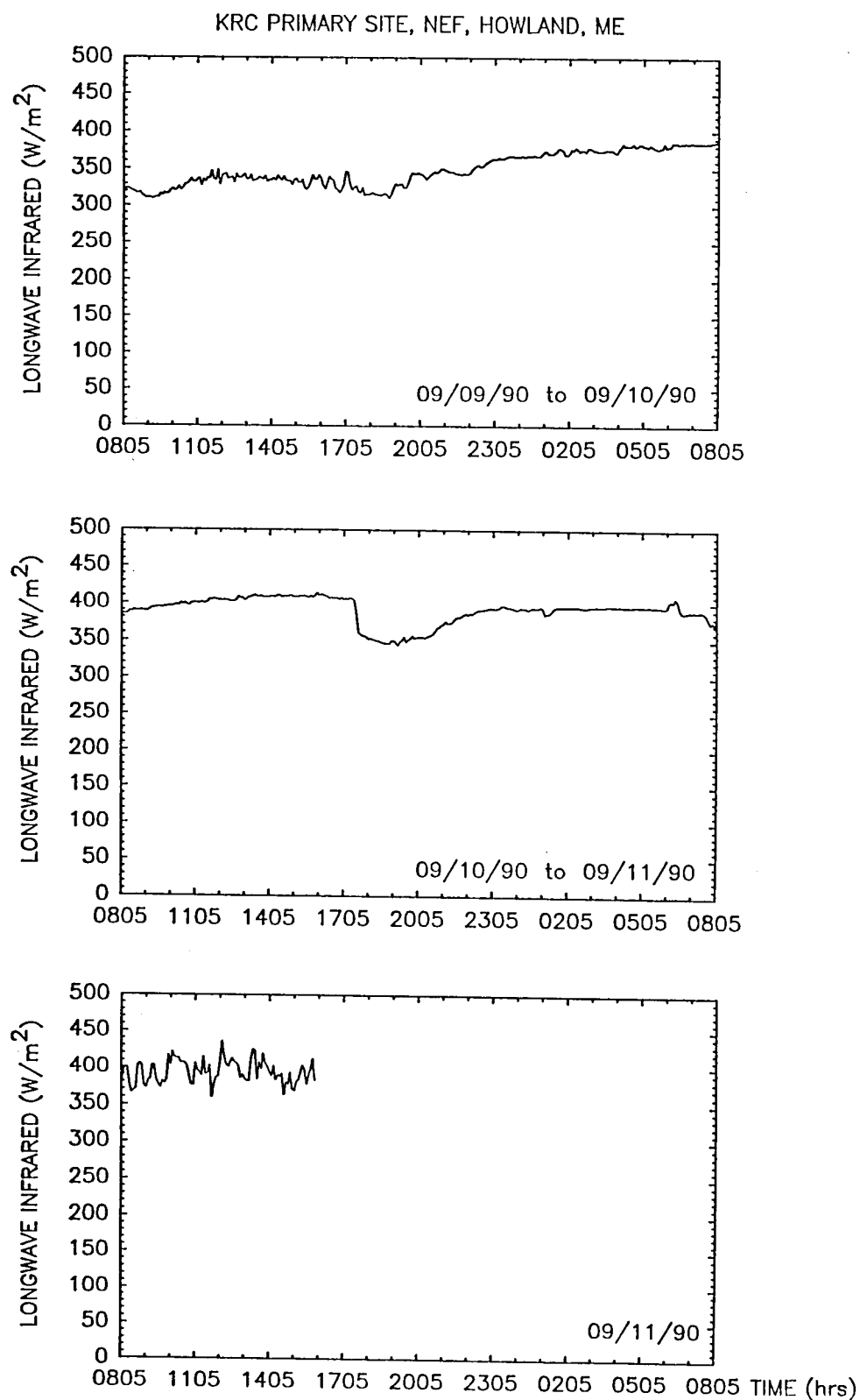


Figure A.3: Longwave Infrared (W/m^2)
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

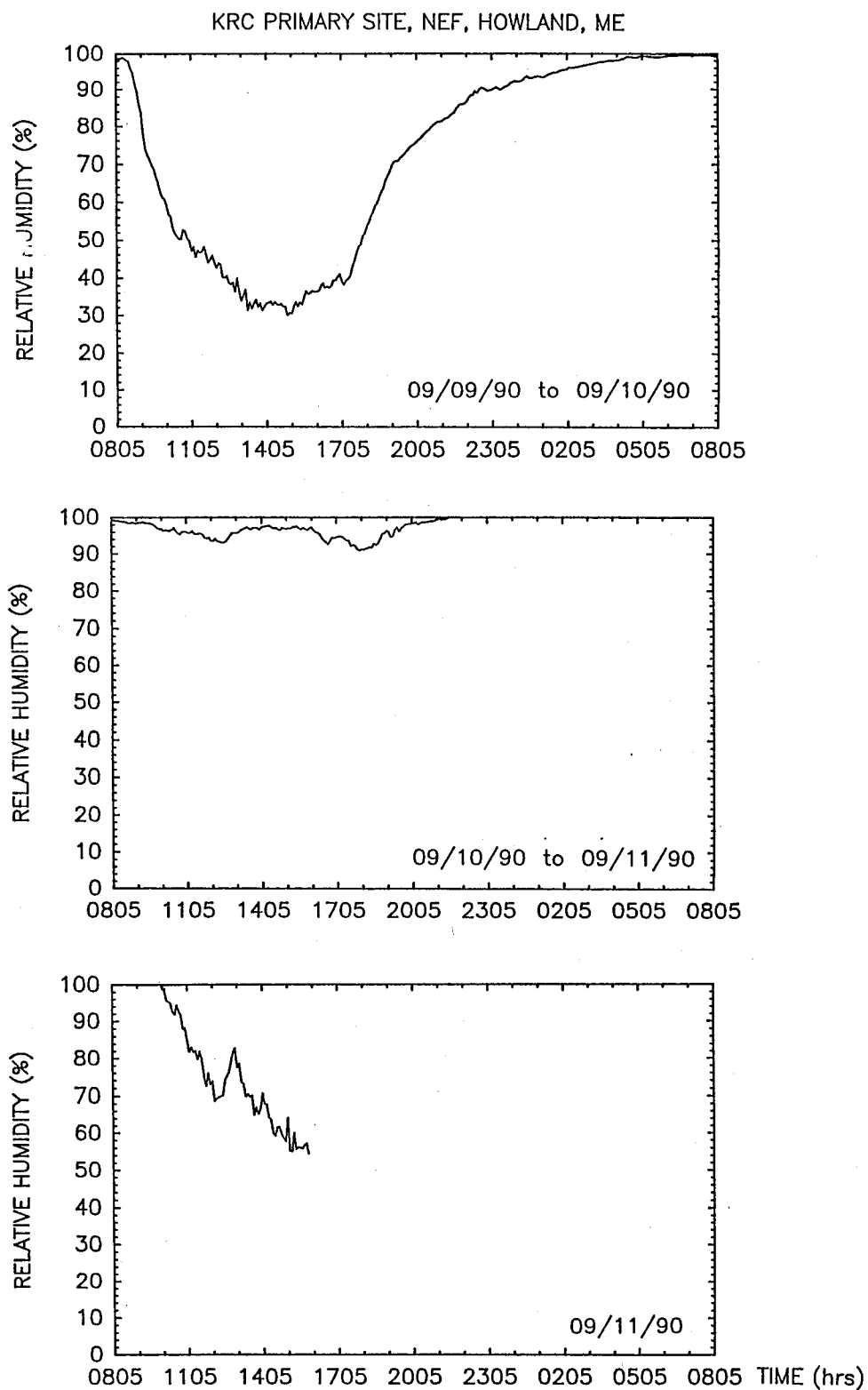


Figure A.4: Relative Humidity (%)

Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

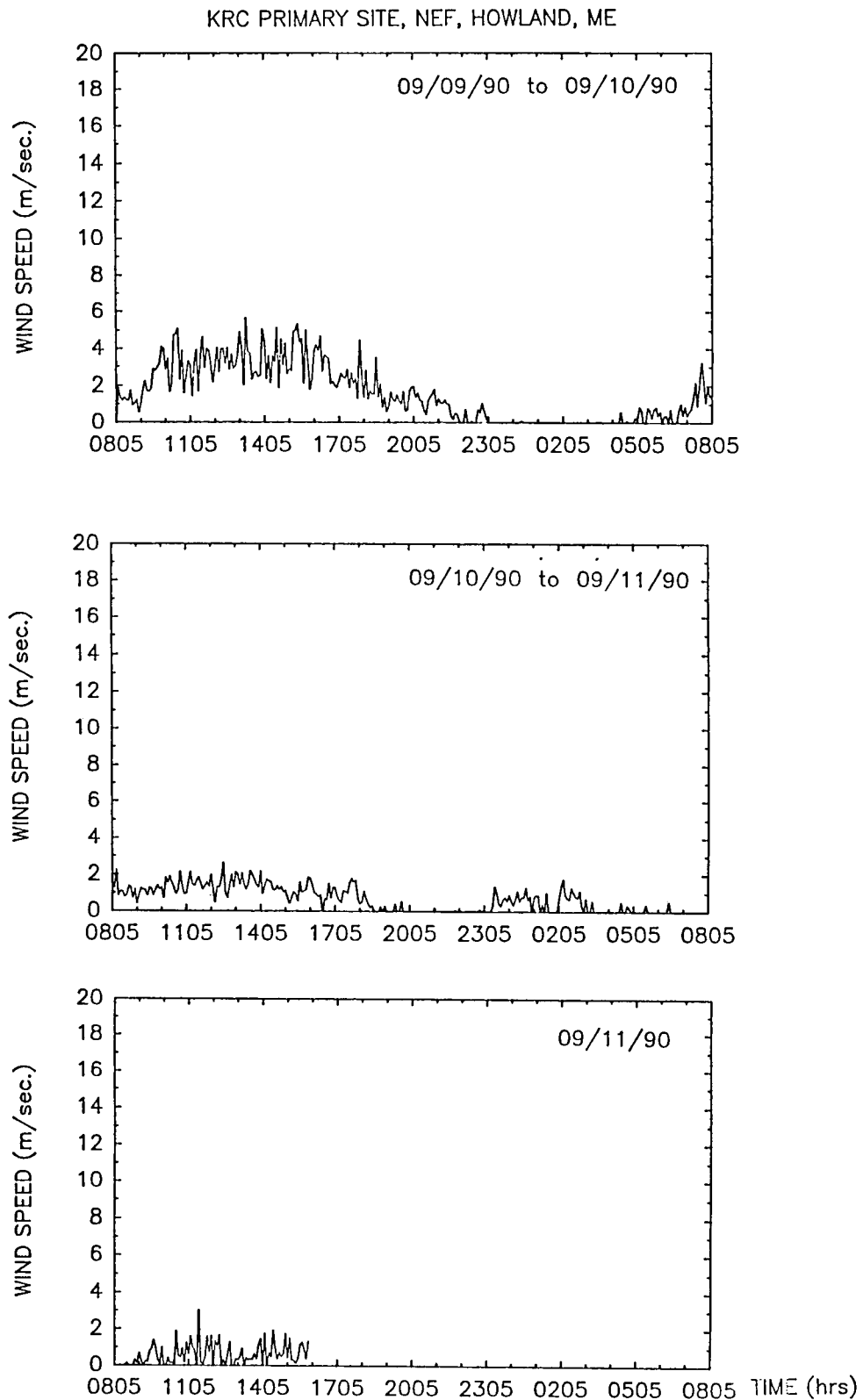


Figure A.5: Wind Speed (m/sec)
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

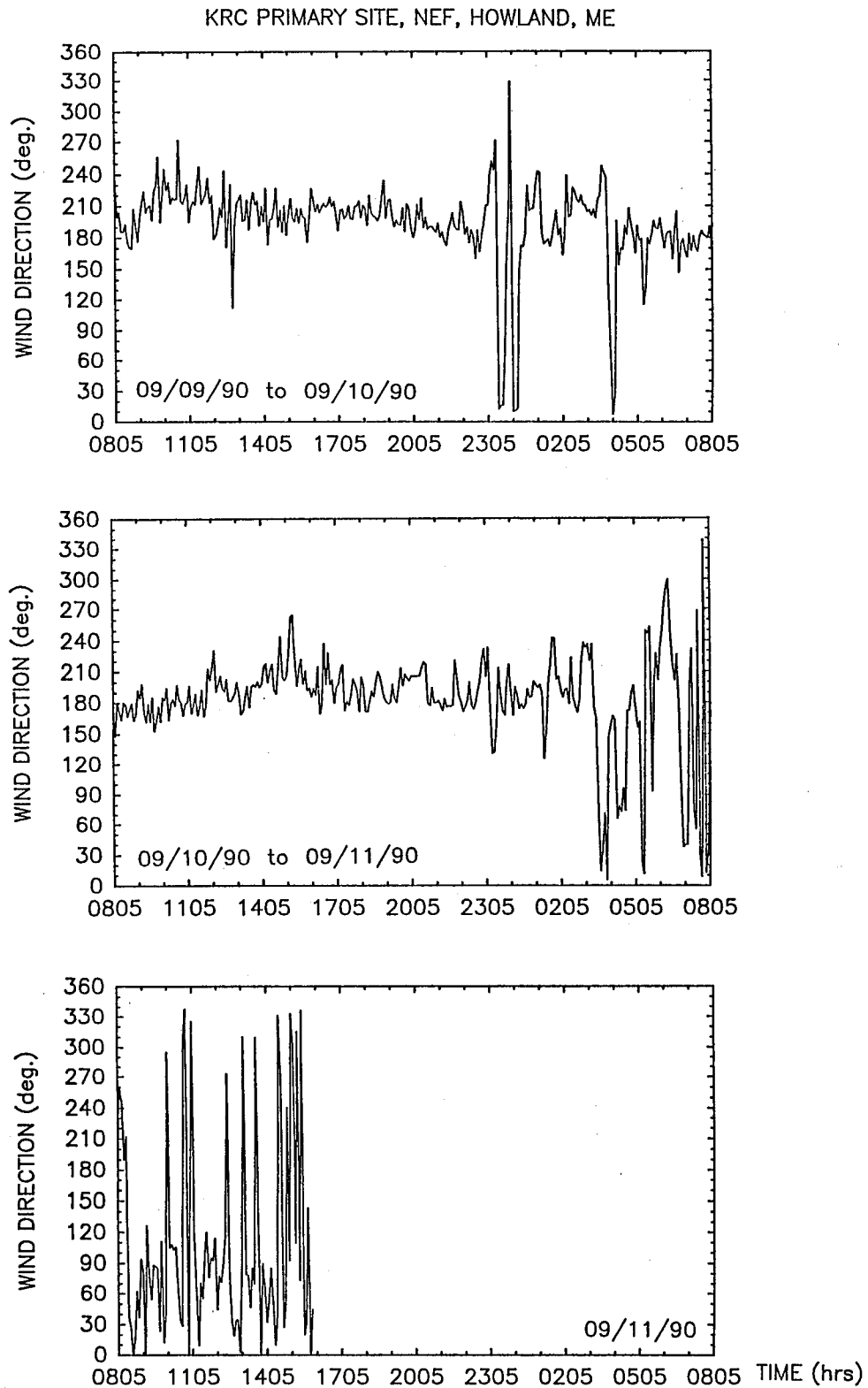


Figure A.6: Wind Direction (Degrees)
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

A.2.2 Data Plots

Figures on the following pages graphically depict the soil temperature data recorded at various depths, at KRC primary site during the FED MAC 1990 experiment. Data from soil temperatures are depicted in terms of comparing readings from the thermocouples at the meteorological station, set at specific depths, across time. (A schematic of the location of the meteorological station was given in Section 5.1. in the main text of this report.) Figures A.7 and A.8 compare soil temperature readings across time at 0, 1, and 5 cm, and at 10, 20, and 50 cm; respectively.

A.3 Forest Edge Soil Temperature Transect Data

A.3.1 Description of Data, Files and File Format

Information on soil temperatures was collected from the probes set for the soil temperature transect into the forest edge. All readings were automatically recorded at five minute intervals by the meteorological computer. These files contain a two-line header that identifies the file type, date, and test site at which the data was collected. An excerpt of a soil temperature transect data file is shown in Table A.4.

Files "ST090990.TRA" and "ST091090.TRA" contain data from the probes set for the soil transect into the forest edge, for 09 September, and 10-11 September, respectively. Their format is:

```
TIME, CH41, CH42, CH43, CH44, CH45, CH46, CH47, CH48, CH49, CH50, CH51, CH52
FORMAT(I4,12F9.3)
```

where:

TIME	Time of day (0000 to 2400 hours)
CH41	Soil Temperature (°C), Location A, 5 cm. depth
CH42	Soil Temperature (°C), Location A, 0 cm. depth
CH43	Soil Temperature (°C), Location B, 5 cm. depth
CH44	Soil Temperature (°C), Location B, 0 cm. depth
CH45	Soil Temperature (°C), Location C, 5 cm. depth
CH46	Soil Temperature (°C), Location C, 0 cm. depth
CH47	Soil Temperature (°C), Location D, 5 cm. depth
CH48	Soil Temperature (°C), Location D, 0 cm. depth
CH49	Soil Temperature (°C), Location A, 15 cm. depth
CH50	Soil Temperature (°C), Location B, 15 cm. depth
CH51	Soil Temperature (°C), Location C, 15 cm. depth
CH52	Soil Temperature (°C), Location D, 15 cm. depth

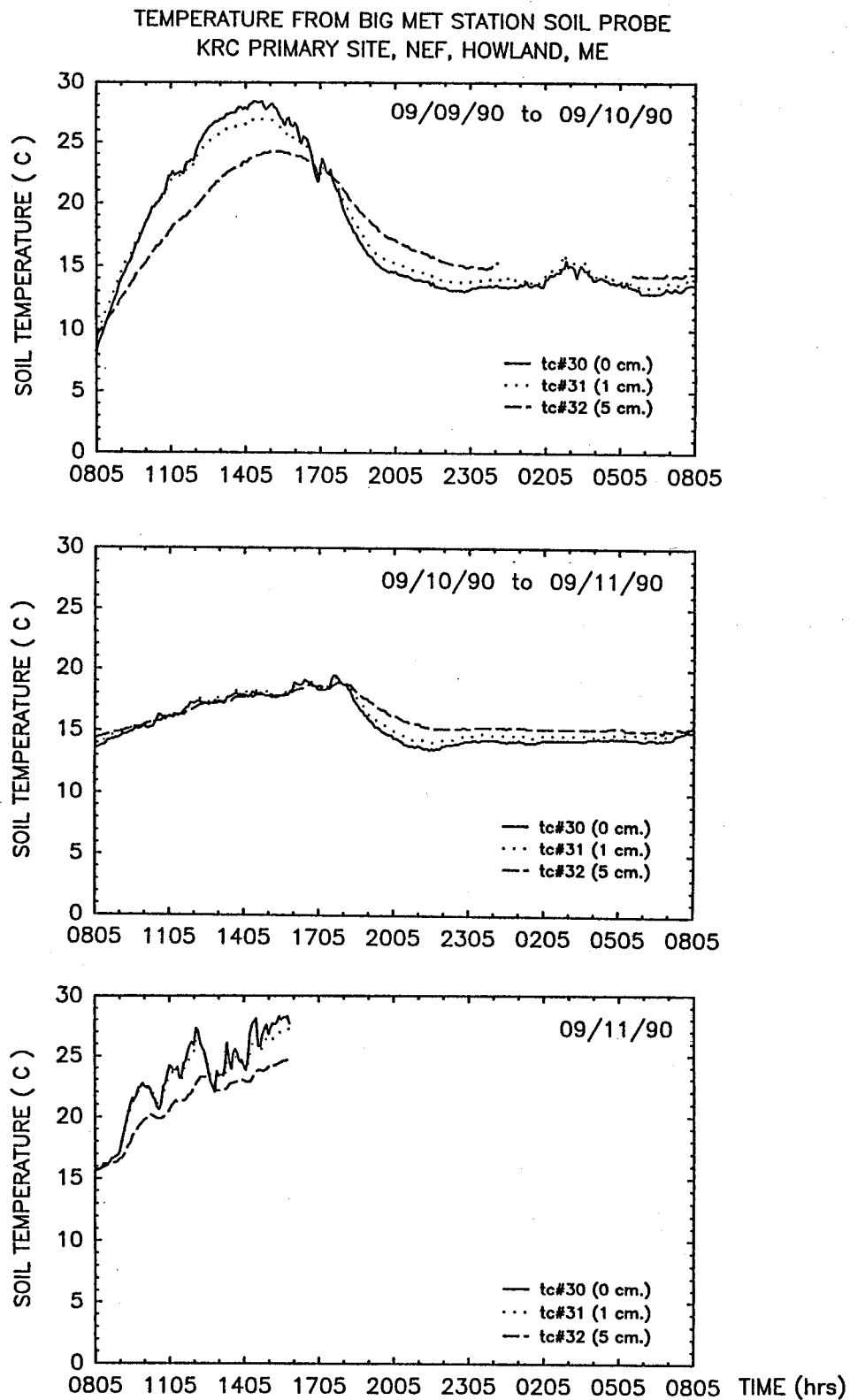


Figure A.7: Soil Temperatures (°C) at 0, 1, and 5 cm Depths, Main Soil Probe
Recorded at KRC Primary Site meteorological tower soil probe in open field, NEF, Howland, Maine for dates shown.

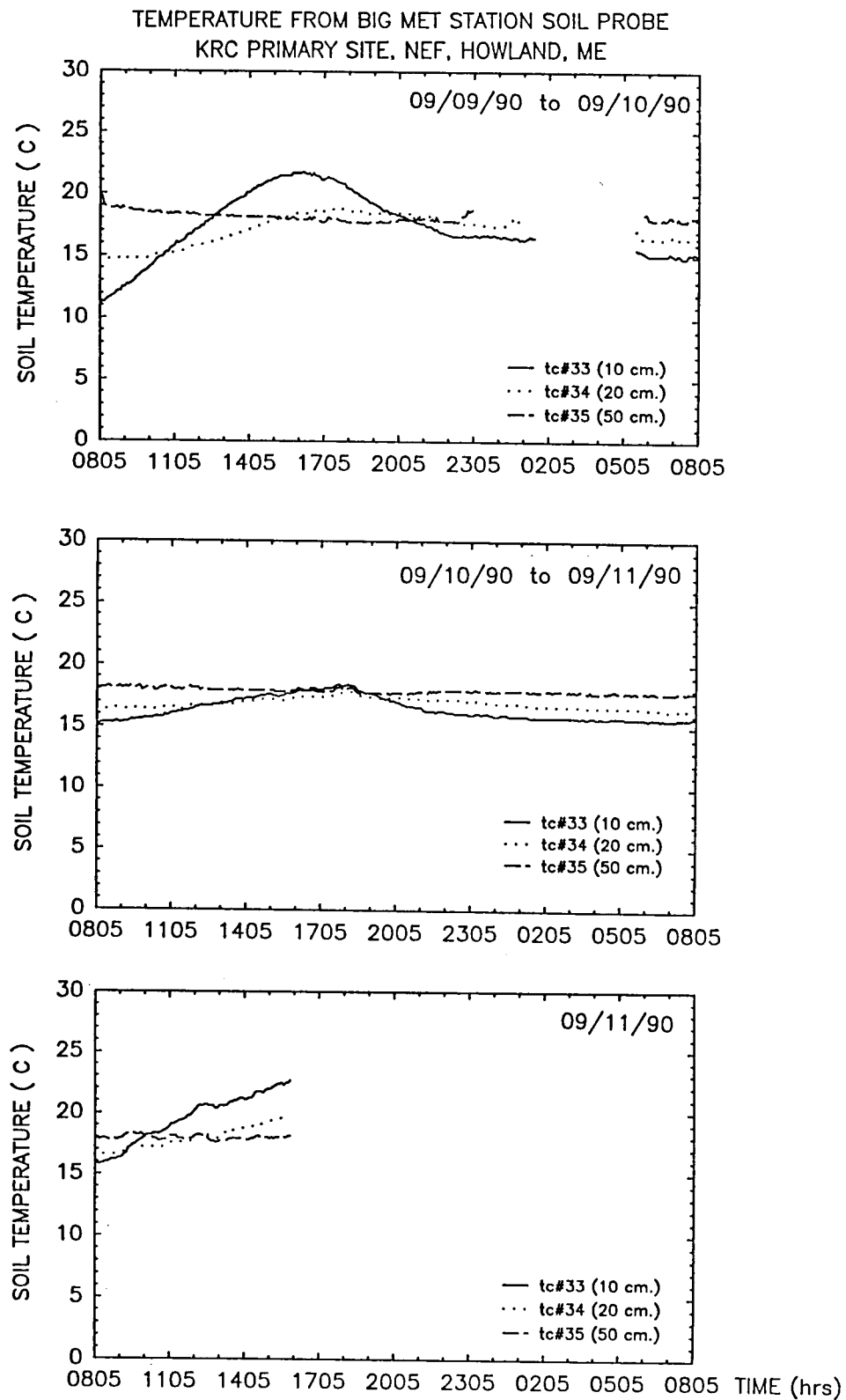


Figure A.8: Soil Temperatures (°C) at 10, 20, and 50 cm Depths, Main Soil Probe

Recorded at KRC Primary Site meteorological tower soil probe in open field, NEF, Howland, Maine for dates shown.

Graphic presentations of soil transect data are included in the discussion section in the main body of this report.

A.4 Leaf Area Index of Treeline Gap

Leaf density or Leaf Area Index (LAI) is measured to help model thermal process essential to plant growth. These process, which are all dependent on the density and orientation of the canopy foliage, include: radiative transfer, conduction, transpiration, evaporation, and gaseous exchange into and out of the canopy. LAI, the total area of vegetative material in a prescribed layer of plant canopy per unit ground area, is used to define the solar shielding factor σ_f . The value of the solar shielding factor ranges from 0, signifying no foliage, to 1, signifying complete radiative blocking.

A.4.1 Testing Procedure

The LICOR LAI-2000 used to measure LAI has an optical sensor that consists of a group of five ring-shaped radiation detectors arranged concentrically. The LAI-2000 computes a gap fraction, which is the ratio of light transmitted through the canopy to light that is incident on the canopy, for each sensor view ring.

Measurements were performed with two identical LAI-2000 units, designated as ABOVE ("A") and BELOW ("B") units, respectively. Unit A was placed 10 meters east of the KRC meteorological tower so as to obtain an unrestricted field of view of the clear sky, and logged the above canopy readings automatically every 15 seconds. Unit B was manually controlled to record the below canopy values. The logging units were later connected to combine data files, and a canopy LAI computed.

Table A.3: Ground Probe Soil Temperature Data
Excerpt of file "09TC3035" showing 2-line header and data.

```
KRC Ground Probe Temperature Data: 09/09/90.  Howland, ME.
TIME      T00CM      T01CM      T05CM      T10CM      T20CM      T50CM
0805      8.200      8.900      9.100      10.900     14.400     19.600
0810      8.800      9.600      9.800      11.400     14.600     19.800
0815      9.300      10.300     9.900      11.300     14.700     19.100
0820      9.700      10.800     10.200     11.500     14.700     18.900
0825     10.200      11.300     10.400     11.600     14.700     18.800
0830     10.700      11.600     10.700     11.700     14.700     18.800
0835     11.200      12.000     11.000     11.800     14.700     18.800
0840     11.600      12.300     11.200     11.900     14.700     18.800
0845     12.100      12.800     11.400     12.100     14.700     18.900
0850     12.500      13.300     11.700     12.200     14.800     18.800
0855     12.900      13.700     11.800     12.200     14.600     18.700
0900     13.600      14.300     12.300     12.500     14.800     18.900
```

Table A.4: Soil Temperature Transect Data (Wrapped file)
Excerpt of file "090990" showing 2-line header and data (wrapped).

```
KRC Soil Temperatures Transect Data: 09/09/90.  Site Fed Mac test, Howland, ME.
TIME      CH41      CH42      CH43      CH44      CH45      CH46      CH47      CH48
CH49      CH50      CH51      CH52
0805      9.200      8.700      10.300     6.800      10.400     6.700      8.800      4.900
14.900     13.800     13.300     12.100
0810      9.400      8.900      10.300     6.900      10.500     6.800      8.800      5.100
14.900     13.800     13.300     12.100
0815      9.600      9.200      10.300     7.100      10.600     7.000      8.800      5.300
15.000     13.800     13.300     12.100
0820      9.700      9.800      10.400     7.300      10.600     7.300      8.900      5.600
15.000     13.800     13.300     12.200
```

Initial measurements were made according to the location of the sites A, B, C, and D described for the soil temperature transect, in the forest gap (see Figure 5.5 in the main body of the report for a schematic of the soil temperature transect). The data sets listed below show the LAIs at, to the left, and to the right of each thermocouple site. With these and other readings taken deeper in the gap, an average of 40 readings were obtained around the entire gap.

A.4.2 Description of Data, Files and File Format

File "MAINE.LAI" contains LAI and related data. Table A.5 contains an excerpt from this file showing one complete set of measurements. Each set of measurements consists of a one-line header, followed by a set of five parameters - each of which is computed for each of the five view rings - and finally by an ordered sequence of input data values from the A and B units.

The header contains the following information:

FILE, DATE, TIME, HEIGHT, POSITION, LAI, SEL, DIFN, MTA, SEM, SMP

where:

FILE	index number of the set of observations
DATE	date (day and month) on which observations made
TIME	time of day (HR:MIN:SEC, 24-hour clock) observations initiated
HEIGHT	label describing height of instrument
POSITN	label describing location of instrument
LAI	leaf area index computed from the set of observations in the file
SEL	standard error of the LAI determination
DIFN	diffuse non-interceptance, the fraction of sky visible beneath the canopy
MTA	mean tip angle computed from the set of observations in the file
SEM	standard error of the mean tip angle determination
SMP	number of samples

The header is followed by a set of parameters. Five values, corresponding to the five view rings, are given for each parameter:

ANGLES,CNTCT,STDDEV,DISTS,GAPS

where:

ANGLES	the view angle (degrees) of each ring
CNTCT	the average contact number for each ring; calculated as the natural logarithm of the gap fraction divided by the path length ($1/\cos\theta$)

STDDEV standard error of the contact frequencies
 DISTS path length from the sensor to the edge of the canopy; typically, $1/\cos\theta$ is used for the uniform canopy assumption
 GAPS average gap fraction, or transmission through the canopy, for each ring; calculated from sets of A (above canopy, or incident light) and B (beneath canopy, or transmitted light) readings

Finally, input data in the format

UNIT,OBSNO,TIME,RING1,RING2,RING3,RING4,RING5

where:

UNIT identifier of LAI-2000 unit on which observations recorded:
 A (above canopy, or incident light)
 B (beneath canopy, or transmitted light)
 OBSNO observation number in sequence of 10 observations/file
 TIME time of day (HR:MIN:SEC, 24-hour clock) at which observations recorded
 RING1 amount of light measured by the 7° ring
 RING2 amount of light measured by the 23° ring
 RING3 amount of light measured by the 38° ring
 RING4 amount of light measured by the 53° ring
 RING5 amount of light measured by the 68° ring

The measure of the amount of light registered by RING1, etc is a calibrated, dimensionless reading. A blank line separates each set of measurements from the next set.

A.5 Thermal Imagery and Spot Radiometric Data

A.5.1 Description of Thermal Imagery and Data

Thermal imagery from the Maine field test is digitized for processing, using a PC-based Data Translation frame grabber. Each binary digit frame is supplemented by information from the corresponding frame of blackbody imagery, and converted into a calibrated temperature pixel frame. The temperature value assigned to a pixel is an apparent, or blackbody equivalent temperature, i.e., a blackbody at that temperature would emit the equivalent amount of radiation, in band, that was detected by the thermal imager.

A.5.2 Thermal Imagery, Primary Site

Description of Data, Files and File Format

Thermal imagery for the primary site was collected using the commercially available IR imaging system, Inframetrics model 610. As shown in the file excerpt in Table A.6, each file has a one-line header that identifies the file type, date, and test site at which the data was collected. Variables in the header, and the format of the header are:

FRAMENO,DATE,TIME,DESCRIB,RANGE

FORMAT(5X,I5,11X,I6,1X,I4,6X,A20,5X,I4)

where:

FRAMENO	Frame number assigned to image
DATE	Month, Day, and Year (MMDDYY) of test
TIME	Time of day (24-hour clock)
DESCRIB	Brief description of image contents
RANGE	Temperature range ($^{\circ}\text{C}$). Common values are $2^{\circ}, 5^{\circ}, 10^{\circ}, 20^{\circ}, 50^{\circ}, 100^{\circ}, 200^{\circ}$.

The following records give line-by-line data on pixel temperatures, in a format that depends on sensor capabilities and resolution of the image data. Typical image sizes are 128x128 pixels, 256x256 pixels, or 512x512 pixels. The format of the pixel temperature data is:

PTEMP(I,J)

FORMAT(M(S(16I5,/)))

where:

$I = 1, 2, \dots, R$ where R = total number of Rows in image (128, 256, or 512)
 $J = 1, 2, \dots, C$ where C = total number of Columns in image (128, 256, or 512)
 $S = R/16$

and

PTEMP(I,J)	Temperature of the pixel in row I, column J stated as degrees Kelvin times 10 .
------------	---

Pixel values are thus read from the upper left-hand corner of the image, row by row, ending with the pixel in the lower right-hand corner of the image. Note that pixel temperatures are stated as degrees Kelvin times 10 and thus will appear as rather large values in the data file. **Pixel values of PTEMP(I,J)=0 indicate border pixels, and are not elements of the image.** All image data files must therefore be manipulated to convert temperature

Table A.5: Leaf Area Index Data

Excerpt of file "MAINE.LAI" showing file header and data.

FILE	DATE	TIME	HEIGHT	POSITIO	LAI	SEL	DIFN	MTA	SEM	SMP
17	11 SEP	17:09:42	KNEEHI	OMNI	4.14	0.07	0.033	41	0	40
ANGLES	7.000	23.00	38.00	53.00	68.00					
CNTCT#	3.330	2.905	2.369	2.171	1.666					
STDDEV	0.920	0.709	0.390	0.291	0.134					
DISTS	1.008	1.087	1.270	1.662	2.670					
GAPS	0.035	0.043	0.050	0.028	0.012					
A 1	17:10:01	14.00	10.73	10.26	12.29	12.79				
B 2	17:09:54	0.309	0.565	0.395	0.260	0.134				
A 3	17:10:01	14.00	10.73	10.26	12.29	12.79				
B 4	17:09:57	0.277	1.125	0.489	0.172	0.124				
A 5	17:10:01	14.00	10.73	10.26	12.29	12.79				
B 6	17:10:00	0.998	0.724	1.136	0.580	0.242				
A 7	17:10:01	14.00	10.73	10.26	12.29	12.79				
B 8	17:10:03	0.760	0.471	0.669	0.472	0.150				
A 9	17:10:01	14.00	10.73	10.26	12.29	12.79				
B 10	17:10:06	0.760	0.525	0.641	0.468	0.169				
A 11	17:10:01	14.00	10.73	10.26	12.29	12.79				
B 12	17:10:09	0.444	0.612	1.268	0.415	0.217				
A 13	17:10:17	14.00	10.84	10.20	12.28	12.76				

Table A.6: Segment of Digitized Image Temperature File

Excerpt of image file showing 1-line header and pixel temperature values.

FRM#:	75	DATE&TIME:	090990	1308	DESC:	tree	RNG:	50	LVL:	0.0					
2537	2549	2533	2549	2553	2549	2537	2557	2541	2549	2549	2553	2553	2545	2537	2545
2545	2533	2545	2553	2565	2545	2545	2549	2541	2561	2565	2549	2553	2549	2545	2553
2541	2549	2545	2549	2541	2545	2541	2553	2549	2541	2545	2537	2537	2545	2537	2541
2553	2553	2537	2541	2557	2557	2537	2545	2545	2553	2553	2545	2537	2553	2565	2541
2549	2553	2537	2557	2537	2553	2553	2541	2541	2557	2557	2549	2533	2541	2553	2545
2545	2533	2541	2549	2541	2537	2549	2549	2549	2541	2537	2549	2541	2541	2545	2549
2537	2549	2541	2537	2553	2553	2541	2549	2541	2549	2529	2561	2533	2533	2525	2541
2533	2553	2541	2537	2541	2545	2545	2537	2541	2545	2545	2549	2541	2561	2525	2541
2537	2545	2549	2541	2553	2541	2553	2545	2549	2545	2541	2549	2549	2537	2541	2545
2541	2549	2549	2541	2541	2549	2537	2541	2545	2541	2549	2549	2553	2541	2553	2557
2553	2541	2541	2545	2545	2545	2553	2553	2545	2541	2537	2541	2549	2541	2545	2549
2533	2541	2541	2545	2541	2541	2545	2553	2545	2533	2545	2549	2545	2537	2541	2545
2541	2549	2533	2545	2541	2541	2545	2545	2541	2549	2541	2545	2533	2541	2549	2541
2541	2545	2541	2545	2545	2533	2537	2553	2537	2545	2541	2533	2541	2541	2545	2541
2549	2537	2549	2529	2537	2545	2537	2549	2541	2537	2529	2549	2545	2533	2541	2541
2537	2533	2545	2533	2541	2537	2529	2541	2549	2549	2545	2549	2545	2537	2525	2733

values to the desired scale, and to cause any zero values encountered in the file to be treated as border pixels.

Files for the primary site are broken into three categories: gap, deciduous, and mixed. Table A.7 lists all files available with gray-level pixel values. Tables A.8 and A.9 list files whose pixel values are expressed as apparent or blackbody-equivalent temperatures, for gap imagery and mixed species imagery, respectively.

A.5.3 Data Relating to Sample Imagery

Statistics were calculated for selected scene components, including expanses of deciduous vegetation along the forest edge, expanses of coniferous vegetation along the forest edge, a live tree trunk, and a dead tree trunk. These statistics were graphically depicted in Figures 5.23 through 5.36 in the main body of the report.

Data obtained using a spot radiometer provided by Dr. James Smith, NASA/Goddard Space Flight Center, is shown in Table A.10.

Description statistics, Coniferous treeline FED MAC, Maine, 09/90

FRM	MMDDYY	TIME	#ROW	#COL	MEAN	SDEV	MAX	MIN	VAR	NPIX
061	090990	1909	r-69	c-76	12.008	0.284	13.100	11.100	0.081	5244.000
068	090990	2020	r-52	c-73	11.550	0.168	12.100	11.000	0.028	3796.000
075	090990	2113	r-52	c-73	11.234	0.170	11.800	10.600	0.029	3796.000
082	090990	2204	r-52	c-73	10.898	0.217	11.600	10.200	0.047	3796.000
089	090990	2308	r-52	c-73	10.537	0.133	11.100	10.100	0.018	3796.000
096	091090	0003	r-52	c-73	10.112	0.174	11.300	09.700	0.030	3796.000
103	091090	0110	r-52	c-73	09.905	0.165	10.900	09.400	0.027	3796.000
110	091090	0207	r-62	c-37	10.045	0.113	10.400	09.700	0.013	2294.000
117	091090	0259	r-62	c-37	09.805	0.138	10.400	09.400	0.019	2294.000
138	091090	0407	r-62	c-37	09.430	0.111	09.800	09.100	0.012	2294.000
145	091090	0502	r-62	c-37	10.505	0.154	11.200	10.100	0.024	2294.000
152	091090	0606	r-62	c-37	10.027	0.185	10.600	09.400	0.034	2294.000
159	091090	0702	r-62	c-37	10.650	0.128	11.000	10.200	0.016	2294.000
167	091090	0805	r-62	c-37	11.360	NaN.0	11.600	11.100	-.002	2294.000

Descriptive statistics, Deciduous treeline, FED MAC, Maine, 09/90

FRM	MMDDYY	TIME	#ROW	#COL	MEAN	SDEV	MAX	MIN	VAR	NPIX
061	090990	1909	r-27	c-76	11.336	0.368	12.500	10.100	0.135	2052.000
068	090990	2020	r-26	c-76	10.899	0.195	11.600	10.200	0.038	1976.000
075	090990	2113	r-27	c-76	10.795	0.137	11.300	10.300	0.019	2052.000
082	090990	2204	r-27	c-76	10.150	0.204	10.900	09.500	0.042	2052.000
089	090990	2308	r-27	c-76	10.314	0.110	10.600	09.800	0.012	2052.000
096	091090	0003	r-27	c-76	09.756	0.117	10.100	09.400	0.014	2052.000
103	091090	0110	r-26	c-76	09.680	0.119	10.200	09.300	0.014	1976.000
117	091090	0259	r-26	c-76	09.770	0.117	10.200	09.400	0.014	1976.000
138	091090	0407	r-26	c-76	09.345	0.126	09.900	08.900	0.016	1976.000
145	091090	0502	r-26	c-76	10.569	0.207	11.200	09.800	0.043	1976.000
152	091090	0606	r-26	c-76	10.145	0.260	11.100	09.000	0.067	1976.000
159	091090	0702	r-26	c-76	10.784	0.189	11.700	10.000	0.036	1976.000
167	091090	0805	r-27	c-76	11.408	NaN.0	11.600	11.200	-.001	2052.000

Table A.7: Digitized Thermal Image Data Files

Digitized versions of infrared imagery, with gray-scale pixel values (0-255), from KRC Primary Site, NEF, Howland, Maine.

FILENAME	DATE	TIME	DESCRIPTION	RANGE	AMBIENT	HEATED
a07.a	090990	1114	MIXED	20		
a08.a	090990	1114	BLACK BODY	20	17.6	27.6
a12.a	090990	1114	MIXED	50		
a19.a	090990	1209	MIXED	50		
a20.a	090990	1210	BLACK BODY	50	18.2	28.2
a26.a	090990	1433	MIXED	10		
a27.a	090990	1434	BLACK BODY	10	20	26.4
a33.a	090990	1542	MIXED	10		
a34.a	090990	1543	BLACK BODY	10	20.2	25.1
a38.a	090990	1546	MIXED	10		
a42.a	090990	1659	MIXED	5		
a43.a	090990	1700	BLACK BODY	5	17.2	23.3
a51.a	090990	1828	MIXED	10		
a52.a	090990	1830	BLACK BODY	10	14.3	17.5
a58.a	090990	1905	BLACK BODY	10	12.3	15.3
a59.a	090990	1906	DECID	10		
a60.a	090990	1906	GAP	10		
a61.a	090990	1909	MIXED	10		
a62.a	090990	1910	BLACK BODY	10	12.2	15.0
a63.a	090990	2010	BLACK BODY	5	12.1	13.4
a64.a	090990	2014	GAP	5		
a65.a	090990	2016	BLACK BODY	5	12.0	13.4
a66.a	090990	2018	DECID	5		
a67.a	090990	2019	GAP	5		
a68.a	090990	2020	MIXED	5		
a69.a	090990	2020	BLACK BODY	5	11.9	13.4
a70.a	090990	2103	BLACK BODY	5	11.9	13.4
a71.a	090990	2104	GAP	5		
a72.a	090990	2108	BLACK BODY	5	11.9	13.4
a73.a	090990	2110	DECID	5		
a74.a	090990	2112	GAP	5		
a75.a	090990	2113	MIXED	5		
a76.a	090990	2114	BLACK BODY	5	11.8	13.4
a77.a	090990	2159	BLACK BODY	10	10.5	13.4
a78.a	090990	2200	GAP	10		
a79.a	090990	2202	BLACK BODY	10	10.5	13.4
a80.a	090990	2203	DECID	10		
A81.A	090990	2204	GAP	10		
a82.a	090990	2204	MIXED	10		
a83.a	090990	2205	BLACK BODY	10	10.5	13.4
a84.a	090990	2259	BLACK BODY	5	10.9	12.5
a85.a	090990	2300	GAP	5		
a86.a	090990	2303	BLACK BODY	5	10.9	12.5
a87.a	090990	2306	DECIDEROUS	5		
a88.a	090990	2307	GAP	5		

Table A.7: Digitized Thermal Image Data Files, P. 2 of 7

FILENAME	DATE	TIME	DESCRIPTION	RANGE	AMBIENT	HEATED
a89.a	090990	2308	MIXED	5		
a90.a	090990	2309	BLACK BODY	5	10.9	12.6
a91.a	090990	2359	BLACK BODY	5	10.9	12.6
a92.a	090990	2359	GAP	5		
a93.a	091090	0000	BLACK BODY	5	10.6	12.3
a94.a	091090	0001	DECIDEROUS	5		
a95.a	091090	0002	GAP	5		
a96.a	091090	0003	MIXED	5		
a97.a	091090	0004	BLACK BODY	5	10.6	12.3
a98.a	091090	0103	BLACK BODY	5	10.6	12.4
a99.a	091090	0104	GAP	5		
a100.a	091090	0107	BLACK BODY	5	10.7	12.3
a101.a	091090	0108	DECIDEROUS	5		
a102.a	091090	0109	GAP	5		
a103.a	091090	0110	MIXED	5		
a104.a	091090	0111	BLACK BODY	5	10.7	12.3
a105.a	091090	0200	BLACK BODY	5	10.6	12.4
a106.a	091090	0201	GAP	5		
a107.a	091090	0204	BLACK BODY	5	10.6	12.4
a108.a	091090	0206	DECIDEROUS	5		
a109.a	091090	0206	GAP	5		
a110.a	091090	0207	MIXED	5		
a111.a	091090	0208	BLACK BODY	5	10.6	12.3
a112.a	091090	0254	BLACK BODY	5	10.7	12.6
a113.a	091090	0255	GAP	5		
a114.a	091090	0256	BLACK BODY	5	10.7	12.5
a115.a	091090	0257	DECIDEROUS	5		
a116.a	091090	0258	GAP	5		
a117.a	091090	0259	MIXED	5		
a118.a	091090	0300	BLACK BODY	5	10.7	12.5
a133.a	091090	400	BLACK BODY	5	10.8	12.4
a134.a	091090	401	GAP	5		
a135.a	091090	404	BLACK BODY	5	10.7	12.6
a136.a	091090	406	DECIDUOUS	5		
a137.a	091090	406	GAP	5		
a138.a	091090	407	MIXED	5		
a139.a	091090	408	BLACK BODY	5	10.6	12.5
a140.a	091090	457	BLACK BODY	5	11.3	12.6
a141.a	091090	457	GAP	5		
a142.a	091090	459	BLACK BODY	5	11.3	12.6
a143.a	091090	500	DECIDUOUS	5		
a144.a	091090	501	GAP	5		
a145.a	091090	502	MIXED	5		
a146.a	091090	502	BLACK BODY	5	11.5	12.6
a147.a	091090	558	BLACK BODY	5	11.7	12.6
a148.a	091090	600	GAP	5		

Table A.7: Digitized Thermal Image Data Files, P. 3 of 7

FILENAME	DATE	TIME	DESCRIPTION	RANGE	AMBIENT	HEATED
a149.a	091090	603	BLACK BODY	5	11.6	12.5
a150.a	091090	604	DECIDUOUS	5		
a151.a	091090	605	GAP	5		
a152.a	091090	606	MIXED	5		
a153.a	091090	607	BLACK BODY	5	11.7	12.6
a154.a	091090	657	BLACK BODY	5	12.0	13.5
a155.a	091090	658	GAP	5		
a156.a	091090	700	BLACK BODY	5	12.0	13.5
a157.a	091090	701	DECIDUOUS	5		
a158.a	091090	701	GAP	5		
a159.a	091090	702	MIXED	5		
a160.a	091090	702	BLACK BODY	5	12.0	13.5
a161.a	091090	703	VISIBLE SCAN	5		
a162.a	091090	758	BLACK BODY	5	12.3	16.7
a163.a	091090	759	GAP	5		
a164.a	091090	802	BLACK BODY	5	12.4	16.4
a165.a	091090	803	DECIDUOUS	5		
a166.a	091090	804	GAP	5		
a167.a	091090	805	MIXED	5		
a168.a	091090	806	BLACK BODY	5	12.4	16.0
a169.a	091090	910	BLACK BODY	5	13.1	14.3
a170.a	091090	912	GAP	5		
a171.a	091090	917	BLACK BODY	5	13.2	14.3
a172.a	091090	918	DECIDUOUS	5		
a173.a	091090	919	GAP	5		
a174.a	091090	919	MIXED	5		
a175.a	091090	920	BLACK BODY	5	13.2	14.3
a176.a	091090	1002	BLACK BODY	5	13.7	14.9
a177.a	091090	1003	GAP	5		
a178.a	091090	1005	BLACK BODY	5	13.8	14.8
a179.a	091090	1006	DECIDUOUS	5		
a180.a	091090	1007	GAP	5		
a181.a	091090	1008	MIXED	5		
a182.a	091090	1009	BLACK BODY	5	13.8	14.8
a183.a	091090	1104	BLACK BODY	5	14.3	15.4
a184.a	091090	1105	GAP	5		
a185.a	091090	1107	BLACK BODY	5	14.4	15.4
a186.a	091090	1108	DECIDUOUS	5		
a187.a	091090	1108	GAP	5		
a188.a	091090	1109	MIXED	5		
a189.a	091090	1110	BLACK BODY	5	14.4	15.4
a190.a	091090	1115	DECIDUOUS VISUAL	5		
a191.a	091090	1115	GAP VISUAL	5		
a192.a	091090	1115	MIXED VISUAL	5		
a193.a	091090	1240	BLACK BODY	5	15.4	19.4
a194.a	091090	1241	GAP	5		
a195.a	091090	1244	BLACK BODY	5	15.3	19.4
a196.a	091090	1245	DECIDUOUS	5		

Table A.7: Digitized Thermal Image Data Files, P. 4 of 7

FILENAME	DATE	TIME	DESCRIPTION	RANGE	AMBIENT	HEATED
a197.a	091090	1246	GAP	5		
a198.a	091090	1247	MIXED	5		
a199.a	091090	1247	BLACK BODY	5	15.4	19.2
a200.a	091090	1406	BLACK BODY	5	15.7	17.9
a201.a	091090	1407	GAP	5		
a202.a	091090	1408	GAP VISUAL		5	
a203.a	091090	1410	BLACK BODY	5	15.6	17.8
a204.a	091090	1412	DECIDUOUS	5		
a205.a	091090	1413	GAP	5		
a206.a	091090	1413	MIXED	5		
a207.a	091090	1414	BLACK BODY	5	15.6	17.8
a208.a	091090	1420	DECIDUOUS VISUAL	5		
a209.a	091090	1420	GAP VISUAL	5		
a210.a	091090	1422	MIXED VISUAL	5		
a211.a	091090	1555	BLACK BODY	5	16.2	17.5
a212.a	091090	1556	GAP	5		
a213.a	091090	1558	BLACK BODY	5	16.2	17.5
a214.a	091090	1558	DECIDUOUS	5		
a215.a	091090	1559	GAP	5		
a216.a	091090	1600	MIXED	5		
a217.a	091090	1601	BLACK BODY	5	16.4	17.7
a218.a	091090	1744	BLACK BODY	5	16.9	18.4
a218b.	091090	1745	GAP	5		
a219.a	091090	1747	BLACK BODY	5	16.7	18.4
a220.a	091090	1748	DECIDUOUS	5		
a221.a	091090	1749	GAP	5		
a222.a	091090	1752	MIXED	5		
a223.a	091090	1753	BLACK BODY	5	16.6	18.3
a224.a	091090	1756	BLACK BODY	5	16.4	18.2
a225.a	091090	1757	DECIDUOUS	5		
a226.a	091090	1758	GAP	5		
a227.a	091090	1759	MIXED	5		
a228.a	091090	1759	BLACK BODY	5	16.4	18.2
a229.a	091090	1818	BLACK BODY	5	15.9	17.6
a230.a	091090	1820	GAP	5		
a231.a	091090	1821	BLACK BODY	5	15.8	17.5
a232.a	091090	1822	DECIDUOUS	5		
a233.a	091090	1823	GAP	5		
a234.a	091090	1823	MIXED	5		
a235.a	091090	1824	BLACK BODY	5	15.8	17.5
a236.a	091090	1826	DECIDUOUS VISUAL	5		
a237.a	091090	1827	GAP VISUAL	5		
a238.a	091090	1828	MIXED VISUAL	5		
a239.a	091090	1837	BLACK BODY	10	14.9	17
a240.a	091090	1838	GAP	10		
a241.a	091090	1842	BLACK BODY	5	14.6	16.8
a242.a	091090	1843	DECIDUOUS	5		
a243.a	091090	1843	GAP	5		

Table A.7: Digitized Thermal Image Data Files, P. 5 of 7

FILENAME	DATE	TIME	DESCRIPTION	RANGE	AMBIENT	HEATED
a244.a	091090	1844	MIXED	5		
a245.a	091090	1845	BLACK BODY	5	14.4	16.8
a246.a	091090	1854	BLACK BODY	10	13.8	16.4
a247.a	091090	1855	GAP	10		
a310.a	091190	256	BLACK BODY	5	13.0	15.5
a311.a	091190	258	GAP	5		
a312.a	091190	300	BLACK BODY	5	12.9	15.5
a313.a	091190	300	DECIDUOUS	5		
a314.a	091190	301	GAP	5		
a315.a	091190	302	MIXED	5		
a316.a	091190	302	BLACK BODY	5	12.9	15.5
a317.a	091190	358	BLACK BODY	5	13.1	15.6
a318.a	091190	359	GAP	5		
a319.a	091190	401	BLACK BODY	5	13.1	15.6
a320.a	091190	402	DECIDUOUS	5		
a321.a	091190	402	GAP	5		
a322.a	091190	403	MIXED	5		
a323.a	091190	404	BLACK BODY	5	13.1	15.5
a324.a	091190	459	BLACK BODY	5	13.2	15.5
a325.a	091190	500	GAP	5		
a326.a	091190	502	BLACK BODY	5	13.2	15.4
a327.a	091190	502	DECIDUOUS	5		
a328.a	091190	503	GAP	5		
a329.a	091190	504	MIXED	5		
a330.a	091190	504	BLACK BODY	5	13.2	15.4
a331.a	091190	608	BLACK BODY	5	13.0	15.4
a332.a	091190	609	GAP	5		
a333.a	091190	612	BLACK BODY	5	13.0	15.4
a334.a	091190	613	DECIDUOUS	5		
a335.a	091190	614	GAP	5		
a336.a	091190	614	MIXED	5		
a337.a	091190	615	BLACK BODY	5	13.0	15.4
a338.a	091190	658	BLACK BODY	5	13.2	15.6
a339.a	091190	659	GAP	5		
a340.a	091190	700	BLACK BODY	5	13.2	15.6
a341.a	091190	701	DECIDUOUS	5		
a342.a	091190	701	GAP	5		
a343.a	091190	702	MIXED	5		
a344.a	091190	702	BLACK BODY	5	13.2	15.6
a345.a	091190	800	BLACK BODY	5	14.1	15.7
a346.a	091190	802	GAP	5		
a347.a	091190	804	BLACK BODY	5	14.2	15.7
a348.a	091190	806	DECIDUOUS	5		
a349.a	091190	807	GAP	5		
a350.a	091190	808	MIXED	5		
a351.a	091190	809	MIXED	5		
a352.a	091190	901	BLACK BODY	5	15.3	16.7
a353.a	091190	907	GAP	5		
a354.a	091190	904	BLACK BODY	5	15.3	16.7

Table A.7: Digitized Thermal Image Data Files, P. 6 of 7

a355.a	091190	905	BLACK BODY	10	15.8	16.9
a356.a	091190	906	DECIDUOUS	10		
a357.a	091190	908	BLACK BODY	20	16.7	17.4
a358.a	091190	909	DECIDUOUS	20		
a359.a	091190	910	GAP	20		
a360.a	091190	910	MIXED	20		
a361.a	091190	911	BLACK BODY	20	17.1	17.6
a362.a	091190	1000	BLACK BODY	20	20.2	25.2
a363.a	091190	1002	GAP	20		
a364.a	091190	1004	BLACK BODY	20	20.0	25.1
a365.a	091190	1005	DECIDUOUS	20		
a366.a	091190	1005	GAP	20		
a367.a	091190	1006	MIXED	20		
a368.a	091190	1007	BLACK BODY	20	19.6	25.0
a369.a	091190	1055	BLACK BODY	20	20.1	26.0
a370.a	091190	1056	GAP	20		
a371.a	091190	1058	BLACK BODY	20	20.6	26.3
a372.a	091190	1059	DECIDUOUS	20		
a373.a	091190	1059	GAP	20		
a374.a	091190	1100	MIXED	20		
a375.a	091190	1101	BLACK BODY	20	20.9	26.7
a376.a	091190	1135	BLACK BODY	20	19.6	28.2
a377.a	091190	1137	GAP	20		
a378.a	091190	1138	BLACK BODY	20	20.3	28.7
a379.a	091190	1139	DECIDUOUS	20		
a380.a	091190	1140	GAP	20		
a381.a	091190	1141	MIXED	20		
a382.a	091190	1144	BLACK BODY	20	21.5	29.4
a383.a	091190	1144	DECIDUOUS	20		
a384.a	091190	1147	MIXED	20		
a385.a	091190	1148	BLACK BODY	20	21.0	29.5
a386.a	091190	1149	GAP	20		
a387.a	091190	1202	BLACK BODY	20	21.8	30.9
a388.a	091190	1203	DECIDUOUS	20		
a389.a	091190	1203	GAP	20		
a390.a	091190	1205	MIXED	20		
a391.a	091190	1205	BLACK BODY	20	21.9	31.3
a392.a	091190	1207	MIXED	20		
a393.a	091190	1208	GAP	20		
a394.a	091190	1208	DECIDUOUS	20		
a395.a	091190	1213	BLACK BODY	20	22.6	32.4
a396.a	091190	1214	DECIDUOUS	20		
a397.a	091190	1215	GAP	20		
a398.a	091190	1216	MIXED	20		
a399.a	091190	1217	BLACK BODY	20	22.1	32.0
a400.a	091190	1226	BLACK BODY	20	21.7	31.9
a401.a	091190	1227	DECIDUOUS	20		

Table A.7: Digitized Thermal Image Data Files, P. 7 of 7

a402.a	091190	1229	GAP	20		
a403.a	091190	1230	MIXED	20		
a404.a	091190	1259	BLACK BODY	20	18.5	28.8
a405.a	091190	1259	DECIDUOUS	20		
a406.a	091190	1300	GAP	20		
a407.a	091190	1301	MIXED	20		
a408.a	091190	1302	BLACK BODY	20	19.1	28.9
a409.a	091190	1311	BLACK BODY	20	19.4	28.8
a410.a	091190	1313	DECIDUOUS	20		
a411.a	091190	1314	GAP	20		
a412.a	091190	1315	MIXED	20		
a413.a	091190	1319	BLACK BODY	20	19.7	29.2
a414.a	091190	1319	DECIDUOUS	20		
a415.a	091190	1320	GAP	20		
a416.a	091190	1322	BLACK BODY	20	20.9	30.2
a417.a	091190	1322	MIXED	20		
a418.a	091190	1342	BLACK BODY	20	21.6	31.9
a419.a	091190	1343	DECIDUOUS	20		
a420.a	091190	1344	BLACK BODY	20	21.9	32.4
a421.a	091190	1345	GAP	20		
a422.a	091190	1346	MIXED	20		
a423.a	091190	1351	BLACK BODY	20	21.8	32.4
a424.a	091190	1418	BLACK BODY	20	21.6	32.4

Table A.8: Thermal Image Data Files of Forest Gap

Infrared imagery, with pixel values expressed as apparent or blackbody-equivalent temperatures, of forest gap area, KRC Primary Site, NEF, Howland, Maine.

FILENAME	DATE	TIME	DESCRIPTION	RANGE
t163	091090	759	GAP	5
t166	091090	804	GAP	5
t170	091090	912	GAP	5
t173	091090	919	GAP	5
t177	091090	1003	GAP	5
t180	091090	1007	GAP	5
t184	091090	1105	GAP	5
t187	091090	1108	GAP	5
t194	091090	1241	GAP	5
t197	091090	1246	GAP	5
t201	091090	1407	GAP	5
t205	091090	1413	GAP	5
t212	091090	1556	GAP	5
t215	091090	1559	GAP	5
t221	091090	1749	GAP	5
t226	091090	1758	GAP	5
t230	091090	1820	GAP	5
t233	091090	1823	GAP	5
t240	091090	1838	GAP	10
t243	091090	1843	GAP	5
t247	091090	1855	GAP	10
t250	091090	1900	GAP	5
t254	091090	1940	GAP	5
t257	091090	1943	GAP	5
t261	091090	2003	GAP	5
t264	091090	2006	GAP	5
t268	091090	2058	GAP	5
t271	091090	2102	GAP	5
t276	091090	2159	GAP	5
t279	091090	2203	GAP	5
t283	091090	2301	GAP	5
t286	091090	2304	GAP	5
t290	091190	0001	GAP	5
t293	091190	0004	GAP	5
t297	091190	0058	GAP	5
t300	091190	0102	GAP	5
t304	091190	0201	GAP	5
t307	091190	0204	GAP	5
t311	091190	258	GAP	5
t314	091190	301	GAP	5
t318	091190	359	GAP	5
t321	091190	402	GAP	5
t325	091190	500	GAP	5
t328	091190	503	GAP	5

Table A.8: Thermal Image Data Files of Forest Gap, P. 2 of 2

t332	091190	609	GAP	5
t335	091190	614	GAP	5
t339	091190	659	GAP	5
t342	091190	701	GAP	5
t346	091190	802	GAP	5
t349	091190	807	GAP	5
t353	091190	907	GAP	5
t359	091190	910	GAP	20
t363	091190	1002	GAP	20
t366	091190	1005	GAP	20
t370	091190	1056	GAP	20
t373	091190	1059	GAP	20
t377	091190	1137	GAP	20
t380	091190	1140	GAP	20
t386	091190	1149	GAP	20
t389	091190	1203	GAP	20
t393	091190	1208	GAP	20
t402	091190	1229	GAP	20
t406	091190	1300	GAP	20
t411	091190	1314	GAP	20
t415	091190	1320	GAP	20

Table A.9: Thermal Image Data Files of Mixed Species Tree Canopy

Infrared imagery, with pixel values expressed as apparent or blackbody-equivalent temperatures, of forest gap area, KRC Primary Site, NEF, Howland, Maine.

FILE NAME	DATE	TIME	COMMENTS
tfm61.mix	09/09/90	1909	
tfm68.mix	09/09/90	2020	
tfm75.mix	09/09/90	2113	
tfm82.mix	09/09/90	2204	
tfm89.mix	09/09/90	2308	
tfm96.mix	09/10/90	0003	
tfm98.mix	09/10/90	0103	
tfm103.mix	09/10/90	0110	
tfm110.mix	09/10/90	0207	
tfm117.mix	09/10/90	0259	
tfm138.mix	09/10/90	0407	
tfm145.mix	09/10/90	0502	
tfm152.mix	09/10/90	0606	
tfm159.mix	09/10/90	0702	
tfm167.mix	09/10/90	0805	
tfm174.mix	09/10/90	0919	
tfm181.mix	09/10/90	1008	
tfm188.mix	09/10/90	1109	
tfm192.mix	09/10/90	1115	VISUAL
tfm198.mix	09/10/90	1247	
tfm206.mix	09/10/90	1413	
tfm210.mix	09/10/90	1422	VISUAL
tfm216.mix	09/10/90	1600	
tfm222.mix	09/10/90	1752	
tfm227.mix	09/10/90	1759	
tfm234.mix	09/10/90	1823	
tfm238.mix	09/10/90	1828	VISUAL
tfm244.mix	09/10/90	1844	
tfm251.mix	09/10/90	1900	
tfm258.mix	09/10/90	1943	
tfm265.mix	09/10/90	2006	
tfm273.mix	09/10/90	2102	
tfm287.mix	09/10/90	2305	
tfm294.mix	09/11/90	0005	
tfm301.mix	09/11/90	0102	
tfm308.mix	09/11/90	0205	
tfm315.mix	09/11/90	0302	
tfm322.mix	09/11/90	0403	
tfm329.mix	09/11/90	0504	
tfm336.mix	09/11/90	0614	
tfm343.mix	09/11/90	0702	
tfm350.mix	09/11/90	0808	
tfm360.mix	09/11/90	0910	
tfm367.mix	09/11/90	1006	
tfm374.mix	09/11/90	1100	

Table A.9: Thermal Image Data Files of Mixed Species Canopy, P. 2 of 2

tfm381.mix	09/11/90	1141
tfm384.mix	09/11/90	1147
tfm390.mix	09/11/90	1205
tfm392.mix	09/11/90	1207
tfm398.mix	09/11/90	1216
tfm403.mix	09/11/90	1230
tfm407.mix	09/11/90	1301
tfm412.mix	09/11/90	1315
tfm417.mix	09/11/90	1322

Table A.10: Spot Radiometric Data

SUBJECT: Hand Held IRT Spot Measurements at KRC Primary Site,
NEF, Howland, ME

<u>VARIABLE</u>	<u>VALUE</u>	<u>VALUE</u>	<u>VALUE</u>	<u>VALUE</u>	<u>VALUE</u>	<u>VALUE</u>	<u>VALUE</u>	<u>VALUE</u>
DAY (09/90)	09	09	09	10	10	10	11	11
BEGIN TIME	1630	1650	1730	0925	1604	1804	1152	1517
MET STN LOC	25.3	20.3	21.0	15.3	20.2	16.8	-99.9	26.9
LOC A	17.2	15.2	17.2	14.6	18.4	15.7	26.9	19.3
LOC B	17.4	15.9	16.1	13.7	17.0	15.9	31.9	22.3
LOC C	16.6	16.1	14.5	13.7	16.4	15.8	25.7	19.2
LOC D	16.0	14.2	15.5	13.5	16.2	15.8	18.3	18.4
MARKER 1	21.6	17.1	15.6	15.1	19.9	16.2	27.6	28.4
MARKER 2	20.9	15.8	14.2	15.5	19.0	14.9	28.7	28.1
TREE TRUNK	17.8	16.9	16.5	13.9	16.9	16.1	38.2	-99.9
BIRCH/SHADE	-99.9	-99.9	-99.9	-99.9	-99.9	15.7	-99.9	18.1
BIRCH/SUN	-99.9	-99.9	-99.9	13.9	17.2	17.5	21.8	22.5
SPRUCE/SHADE	-99.9	-99.9	-99.9	-99.9	-99.9	16.1	17.0	18.6
SPRUCE/SUN	-99.9	-99.9	-99.9	-99.9	16.5	-99.9	22.9	22.3
END TIME	1634	1654	1735	0930	1613	1812	1157	1526

NOTE: The value "-99.9" indicates missing data.

Appendix B

Single Tree Thermal Imagery and Related Data from FED MAC Field Test

Single Tree Thermal Imagery and Measurements

Data to Supplement STAMP Single Tree Analysis

SWOE/FED MAC Field Test, Howland, Maine

Keweenaw Research Center
Michigan Technological University
Houghton, Michigan

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1.0. BACKGROUND

Keweenaw Research Center (KRC) participation in the 1990 Forest Ecosystem Dynamics - Multisensor Aircraft Campaign (FED-MAC) project was part of a data collection and exchange effort of the SWOE Thermal Analysis and Measurement Program (STAMP). This work was conducted in order to acquire information useful for model validation, and for establishing the needs and directions of future SWOE measurement programs.

Field test sites, experimental plans, and data acquisition procedures were described in detail in a preliminary report.¹ Supporting measurements, including meteorological data, soil temperature profiles, and spot radiometric data are also presented in the preliminary report.

1.1. STAMP Single Tree Analysis

Measurements and analysis of thermal response of a single, isolated tree were planned by SPARTA, Inc. KRC tapes of thermal imagery of the single tree were provided to SPARTA, and specific images were designated for further analysis.² The purpose of this report is to describe these specific images and to provide statistical data derived from them, in contribution to the analysis of a tree's thermal response patterns.

2.0. SINGLE TREE SITE

2.1. Summary Description

The individual aspen tree located near the University of Maine monitoring station was imaged on an hourly basis from 11:20 AM, 9 September, 1990 through 3:05 PM, 11 September, 1990. Calibrated thermal infrared (8-12 μm) imagery was obtained using an AGEMA Thermovision 880 imaging system. A time-base correction had to be performed to generate imagery that could be digitized and converted to temperature frames.

2.2. Description of Thermal Image Files

Thermal imagery depicting the single tree site during specific time periods was digitized using a PC-based Data Translation video frame digitizer. The binary digit frames so created were supplemented by calibration information derived from accompanying blackbody imagery and thermocouple data. The binary digit frames were then converted into calibrated temperature pixel frames. Filenames of the temperature frames requested by SPARTA are listed in Table 2-1.

2.3. Thermal Image File Format

Thermal image files described in Table 2-1 are 128x128 pixel ASCII files. They contain a one-line identifying header, followed by records of pixel temperature values of four significant digits, recorded in degrees Kelvin multiplied by ten. The record format is FORMAT(16(16I5)), where each record represents one line of the image, starting with the top line and reading left to right.

¹"Preliminary Report on Maine Field Test: Thermal Imagery and Supporting Measurements", A.M.L. LaHaie, Keweenaw Research Center, Michigan Technological University, Houghton, Michigan. October, 1990.

²From a 23 October, 1990 correspondence with Dr. John R. Hummel, SPARTA, Inc.

Table 2-1. Single Tree Calibrated Temperature Pixel Frames

The image files described below were selected by SPARTA, Inc., to augment their single tree thermal response analysis. Copies of these files are provided on a 3.5 inch high density disk accompanying this report. Image pairs shown for time periods on 09/11/90 were taken from extended imaging sequences during periods of variable cloudiness, when short-term transitions in temperatures in leaf clusters were of interest.

Image Filename	Date Mo/DayTime	Sens. Range	File Description
TMA08.A	09/09 1614	50°C.	Single Tree, Lower Half
TMA10.A	09/09 1804	50	Single Tree, Lower Half
TMA12.A	09/09 2040	5	Single Tree, Lower Half
TMA14.A	09/09 2216	5	Single Tree, Lower Half
TMA16.A	09/10 0014	5	Single Tree, Lower Half
TMA37.A	09/10 1744	20	Single Tree, Lower Half
TMA43.A	09/10 1842	20	Single Tree, Lower Half
TMA49.A	09/10 1909	20	Single Tree, Lower Half
TMA72A.A	09/11 1213	50	Single Tree, Upper Half
TMA72A.B	09/11 1213	50	Single Tree, Upper Half
TMA78A.A	09/11 1317	50	Single Tree, Upper Half
TMA78A.B	09/11 1317	50	Single Tree, Upper Half

3.0. STATISTICS FOR SELECTED IMAGE REGIONS

Descriptive statistics were computed for specific, local regions within the thermal images, including:

- 1) trunk (lower 11 feet, approximately) of single tree
- 2) disturbed, mostly bare soil immediately south of single tree
- 3) ground area (image foreground), short grass cover, west of tree
- 4) brush (image foreground, right), southwest of tree
- 5) leaf area - large leaf cluster in center/right (*vis-a-vis* imager perspective) of tree crown - with southern exposure
- 6) second leaf area - leaf cluster on left side (*vis-a-vis* imager perspective) of tree crown - with northern exposure

3.1. Statistics File and Format

Statistics on the tree trunk and ground cover were obtained from frames 8, 10, 12, 14, 16, 37, 43, and 49 (in files TMA_{nn}.A where nn = 08,10,12,14,16,37,43,49, respectively). Leaf area statistics came from pairs of images lifted from the sequences recorded in frames 72 and 78 (files TMA72A.A, TMA72B.A, TMA78A.A, and TMA78B.A). These statistics are shown in Table 3-1, and are also contained in the file FMTREE1.DAT. The contents and format of FMTREE1.DAT are:

FRAME, SEQ, TIME, AREA, NPIX, MEAN, STDDEV, MAX, MIN

FORMAT(I4,I2,1X,I4,I2,I4,4(1X,F5.2))

where:

FRAME	Frame number from which statistics computed
SEQ	Sequence number, if more than one image with same frame number
TIME	Time of day (0000 - 2400) at which imagery recorded
AREA	Code for image region, or area, which statistics describe: <ol style="list-style-type: none">1) trunk (lower 11 feet, approximately) of single tree2) disturbed, mostly bare soil immediately south of single tree3) ground area (image foreground), short grass cover, west of tree4) brush (image foreground, right), southwest of tree5) leaf area - large leaf cluster in center/right (<i>vis-a-vis</i> imager perspective) of tree crown - with southern exposure6) second leaf area - leaf cluster on left side (<i>vis-a-vis</i> imager perspective) of tree crown - with northern exposure
NPIX	Number of Pixels sample to calculate descriptive statistics
MEAN	Arithmetic mean ($^{\circ}C$) for pixel values in specified image region
STDDEV	Standard Deviation ($^{\circ}C$) for pixel values in specified image region
MAX	Maximum pixel value ($^{\circ}C$) in specified image region
MIN	Minimum pixel value ($^{\circ}C$) in specified image region.

3.2. Statistics Data Plots

Figure 3-1 through Figure 3-5 graphically depict maximum, mean, and minimum apparent temperatures recorded for the tree trunk, soil, ground area, and brush, respectively, at selected times on 09 September, 1990. Figure 3-6 through Figure 3-10 provides the same information for the same set of areas, at selected times on 10 September, 1990. Statistics for leaf areas are plotted in Figures 3-11 and 3-12.

Table 3-1. Descriptive Statistics for Selected Image Regions

FRAME	SEQ	TIME	AREA	NPIX	MEAN	STDDEV	MAX	MIN
8	1	1616	1	92	21.17	3.44	29.90	15.10
10	1	1804	1	92	18.33	2.92	27.60	12.00
12	1	2041	1	94	12.68	0.41	13.50	11.10
14	1	2216	1	92	11.83	0.36	12.40	10.50
16	1	0014	1	92	11.44	0.26	12.3	10.8
37	1	1744	1	92	11.69	2.68	18.80	7.10
43	1	1842	1	92	13.91	3.08	21.00	8.20
49	1	1902	1	94	15.93	1.68	18.70	10.30
8	1	1616	2	24	32.33	3.47	39.50	27.10
10	1	1804	2	32	15.13	1.36	18.40	13.20
12	1	2041	2	24	11.05	0.31	11.40	10.30
14	1	2216	2	24	10.15	0.20	10.50	9.80
16	1	0014	2	32	11.42	0.35	12.1	10.50
37	1	1744	2	24	14.59	3.26	20.30	9.30
43	1	1842	2	24	7.51	2.27	10.90	4.00
49	1	1902	2	24	10.30	1.81	13.20	6.80
8	1	1616	3	25	19.29	2.17	24.70	15.50
10	1	1804	3	25	13.63	1.37	16.40	10.00
12	1	2041	3	36	11.50	0.26	12.00	10.90
14	1	2216	3	30	10.37	0.18	10.70	10.00
16	1	0014	3	36	11.02	0.17	11.40	10.60
37	1	1744	3	25	7.97	1.06	10.20	6.50
43	1	1842	3	25	8.25	1.12	10.40	6.00
49	1	1902	3	25	8.18	1.55	11.20	4.20
8	1	1616	4	99	14.83	1.42	19.50	10.70
10	1	1804	4	99	13.62	1.53	16.40	8.00
12	1	2041	4	99	11.91	0.32	12.40	10.90
14	1	2216	4	99	10.71	0.27	11.20	9.80
16	1	0014	4	99	10.99	0.14	11.30	10.50
37	1	1744	4	99	5.33	0.90	7.30	2.10
43	1	1842	4	99	8.09	1.23	10.90	4.50
49	1	1902	4	99	12.45	1.08	14.70	9.50

(Continued on Next Page)

Table 3-1. Descriptive Statistics for Selected Image Regions, Continued

FRAME	SEQ	TIME	AREA	NPIX	MEAN	STDDEV	MAX	MIN
8	1	1616	5	4	14.50	1.92	16.30	12.30
10	1	1804	5	6	12.60	1.57	15.20	10.80
12	1	2041	5	6	12.22	0.48	12.70	11.30
14	1	2216	5	4	11.17	0.32	11.50	10.90
16	1	0014	5	6	10.98	0.30	11.20	10.60
37	1	1744	5	6	7.18	0.77	8.00	6.00
43	1	1842	5	6	10.37	0.99	11.70	9.50
49	1	1902	5	9	12.18	2.23	15.60	6.40
72	1	1213	6	48	7.71	2.15	11.80	2.20
72	2	1213	6	46	6.59	2.55	11.40	1.00
78	1	1317	6	46	14.54	2.90	22.20	7.40
78	2	1317	6	46	15.31	2.50	20.21	7.80
72	1	1213	7	12	4.20	2.48	7.80	1.00
72	2	1213	7	6	3.27	1.42	5.00	1.40
78	1	1317	7	12	12.57	2.79	16.20	8.20
78	2	1317	7	12	10.63	3.92	15.40	2.20

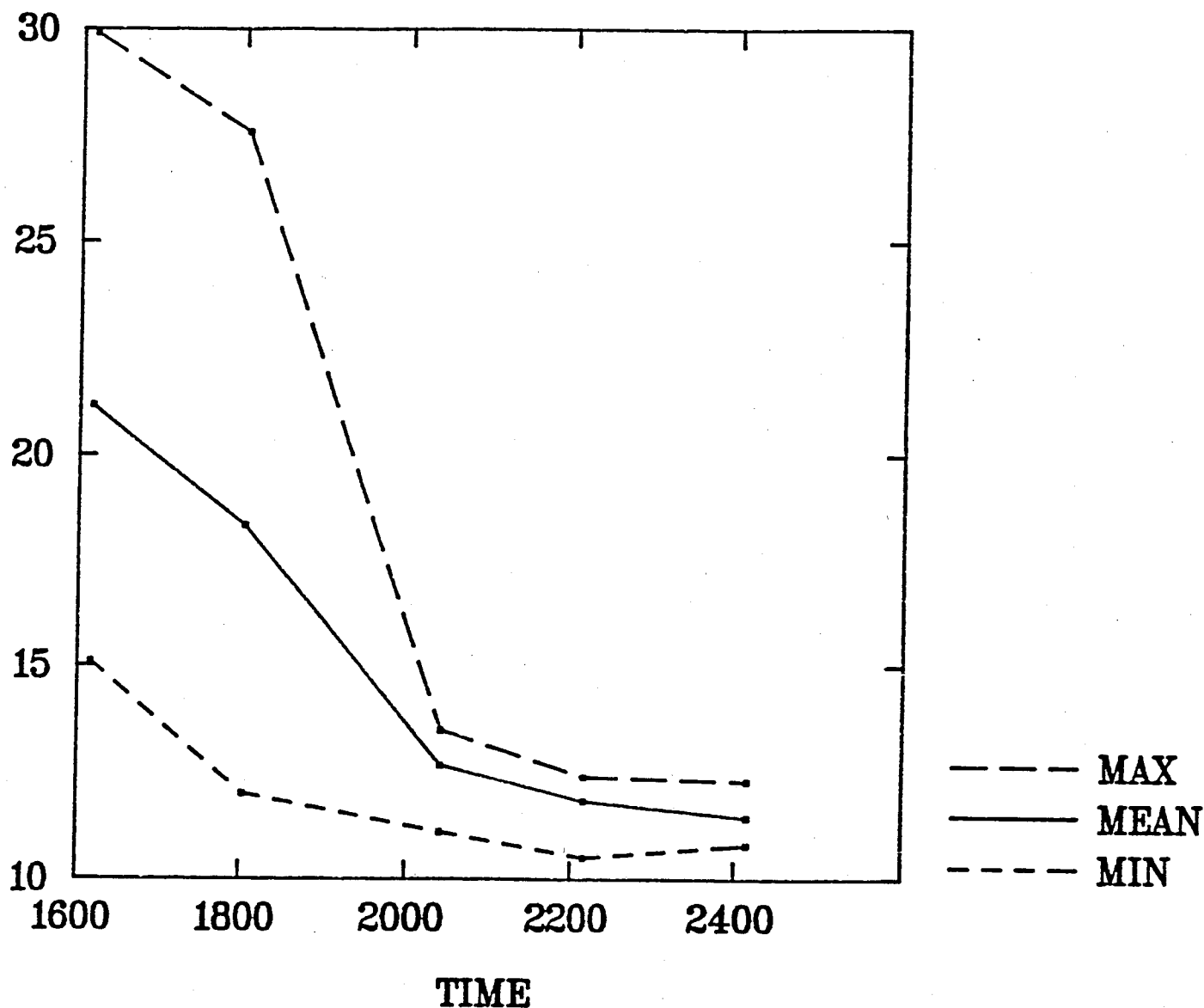


Figure 3-1. Tree Trunk Apparent Temperature Statistics, 09/09/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the trunk of the single tree are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

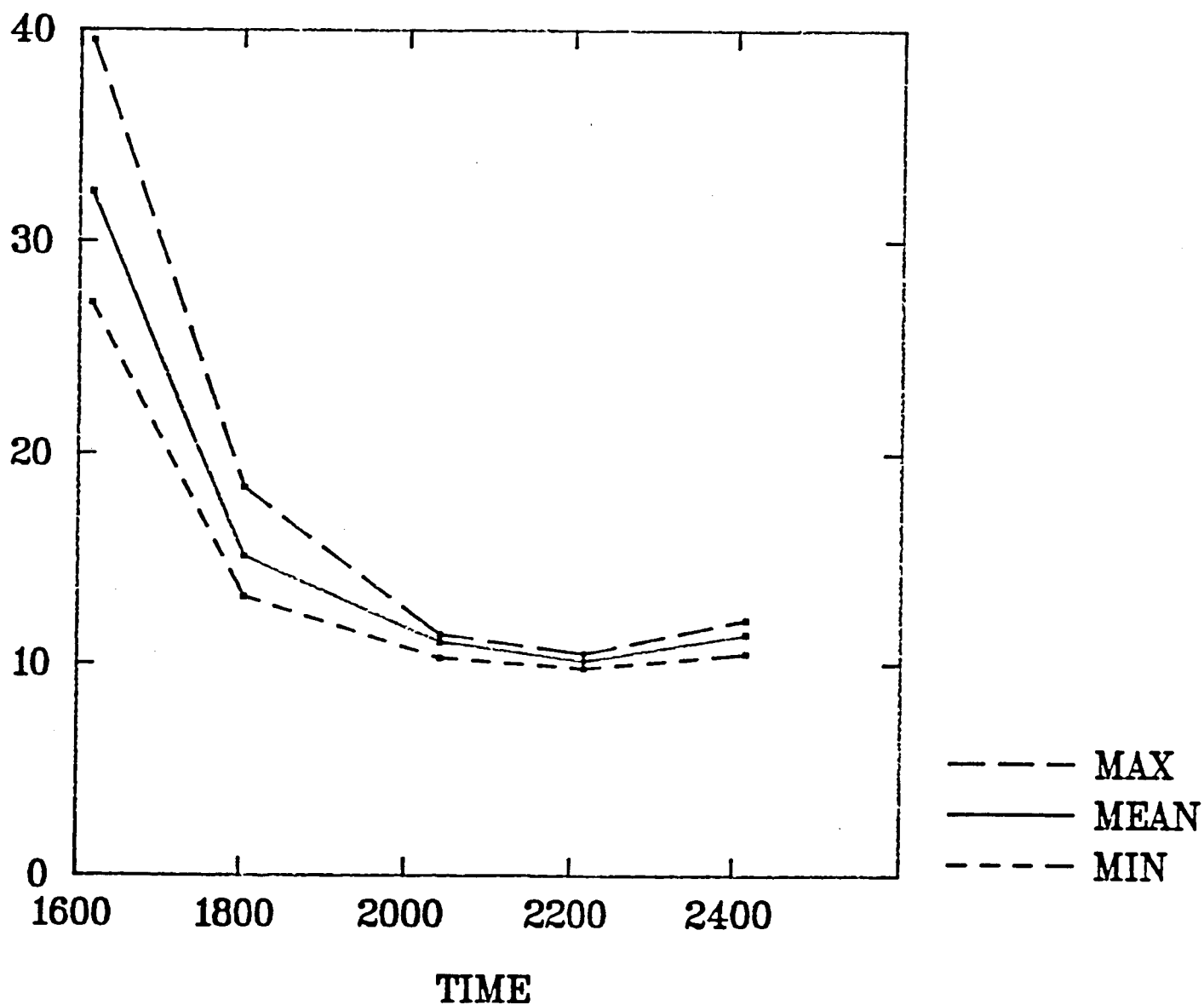


Figure 3-2. Disturbed Soil Apparent Temperature Statistics, 09/09/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the disturbed soil area immediately to the south of the single tree are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

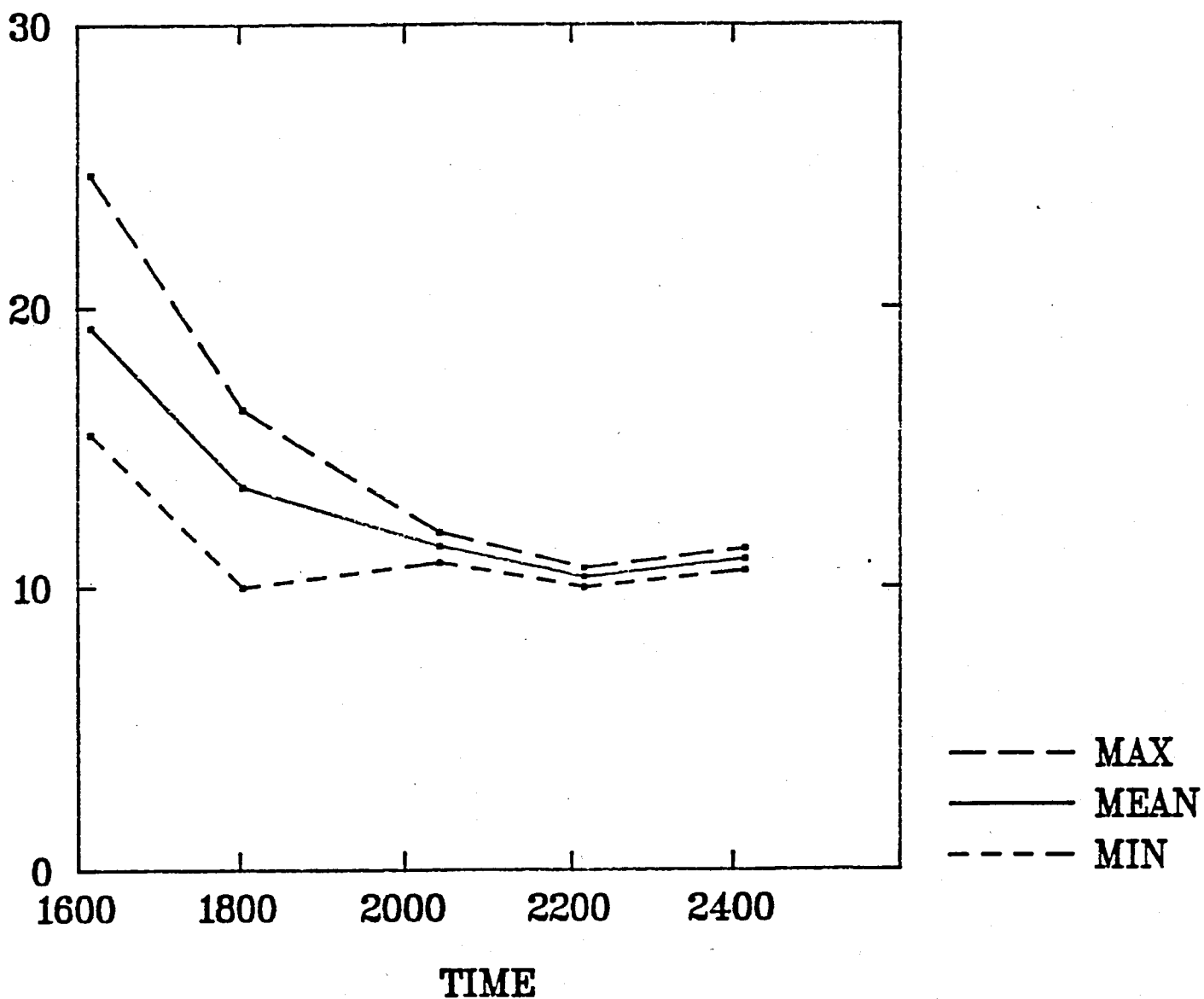


Figure 3-3. Ground Area Apparent Temperature Statistics, 09/09/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the grassy ground area in the image foreground at the single tree site are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

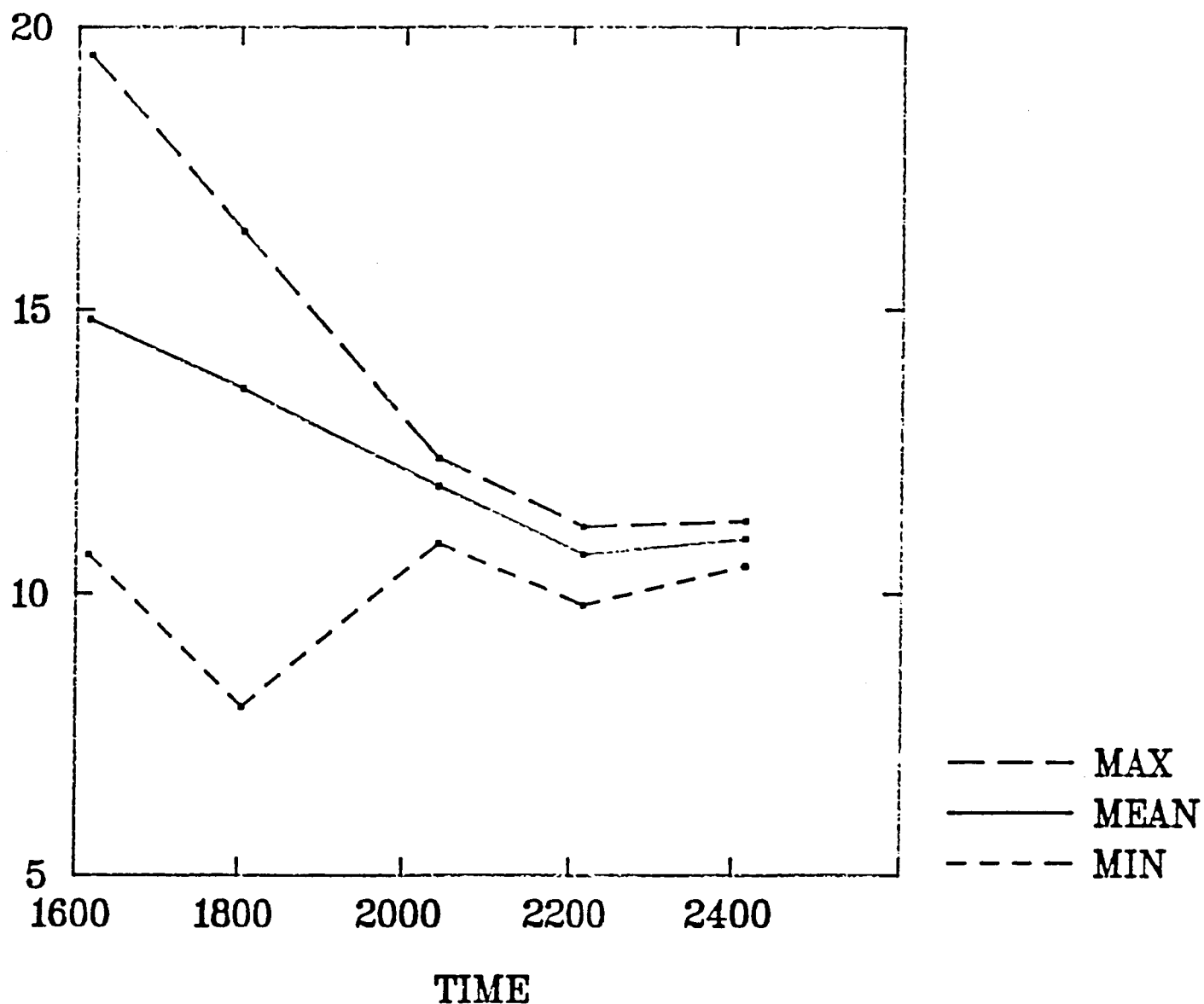


Figure 3-4. Foreground Brush Apparent Temperature Statistics, 09/09/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the brush in the image foreground, lower right corner, at the single tree site are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

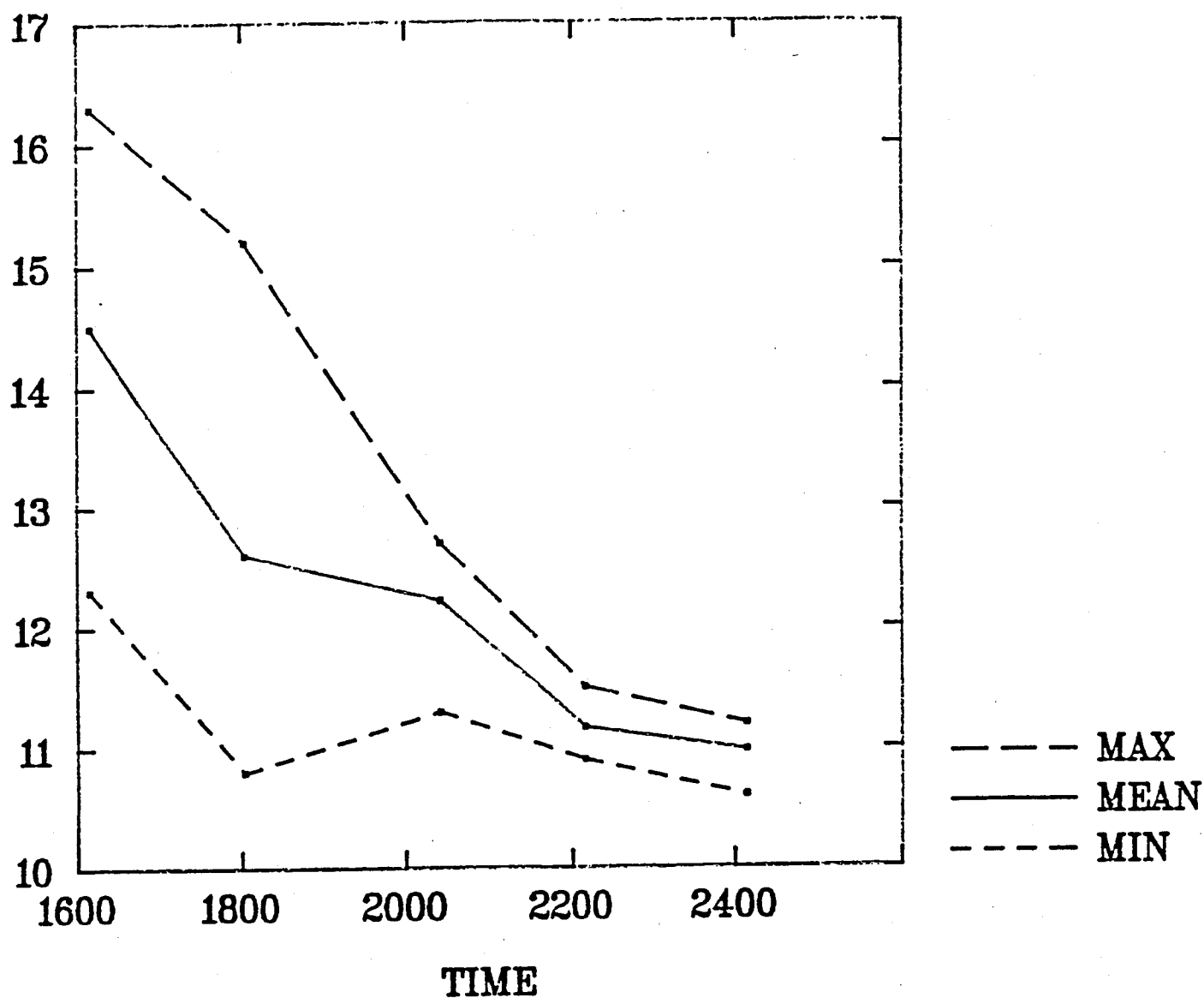


Figure 3-5. Leaf Area Apparent Temperature Statistics, 09/09/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

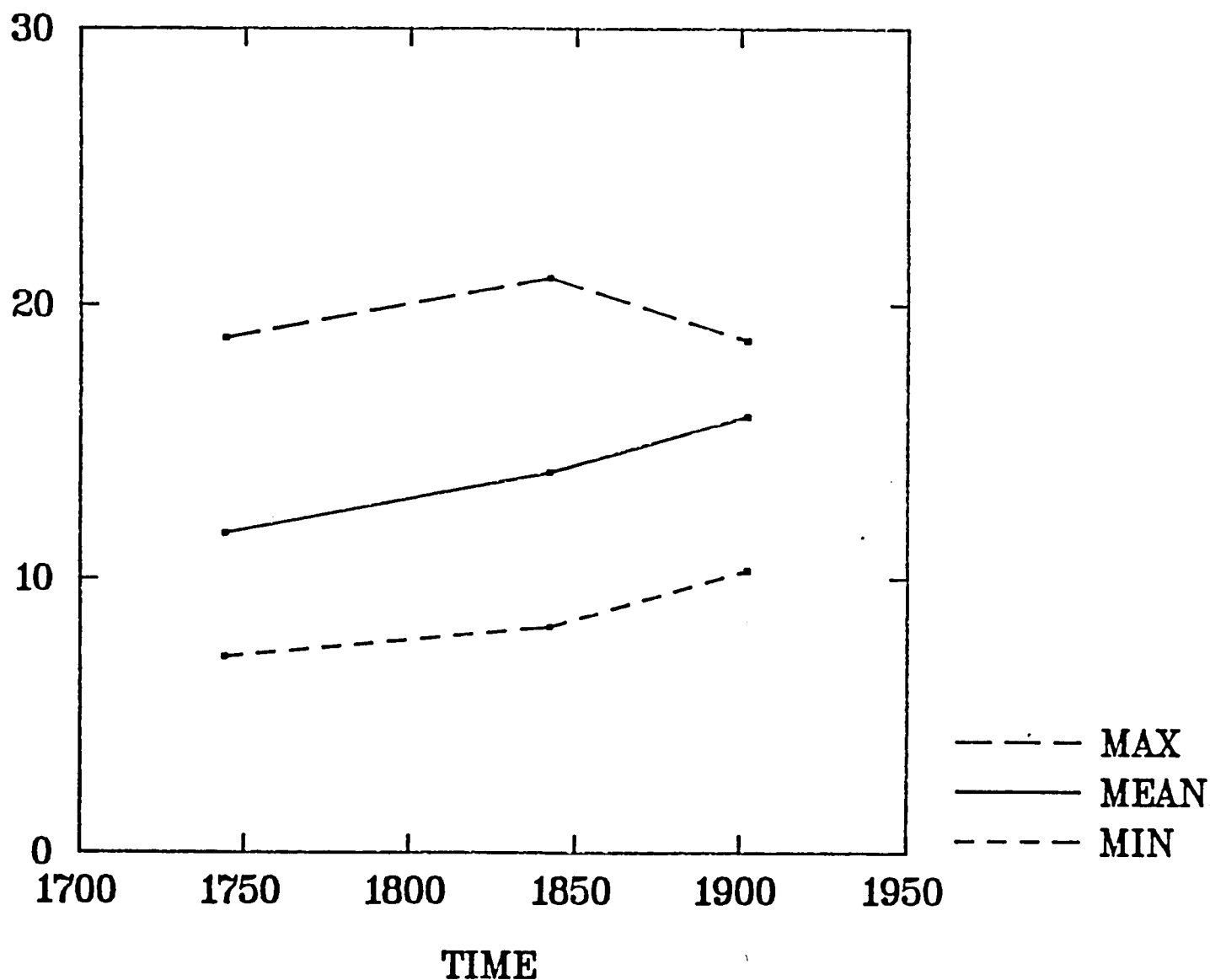


Figure 3-6. Tree Trunk Apparent Temperature Statistics, 09/10/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the trunk of the single tree are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43 and 49.

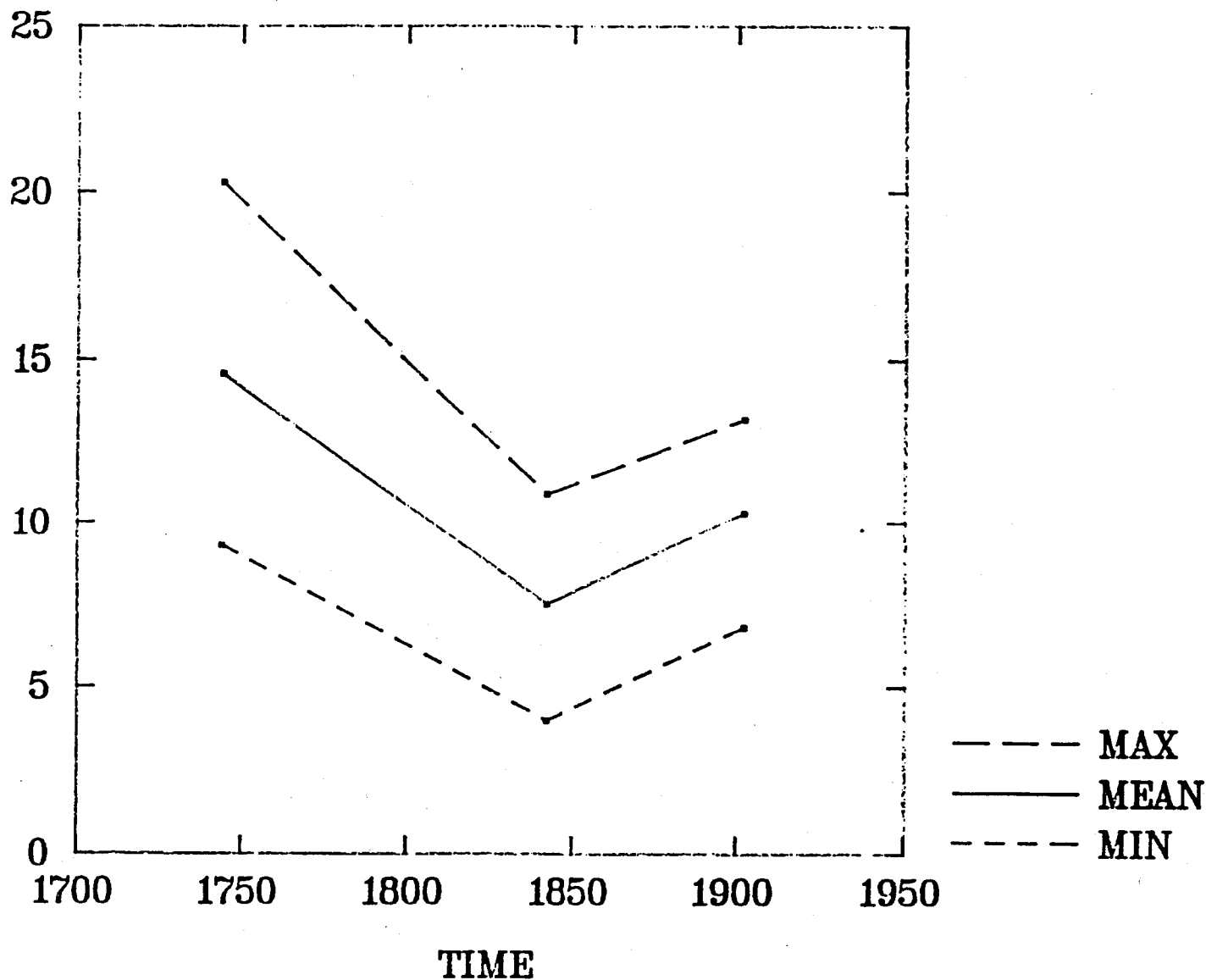


Figure 3-7. Disturbed Soil Apparent Temperature Statistics, 09/10/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the disturbed soil area immediately to the south of the single tree are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43 and 49.

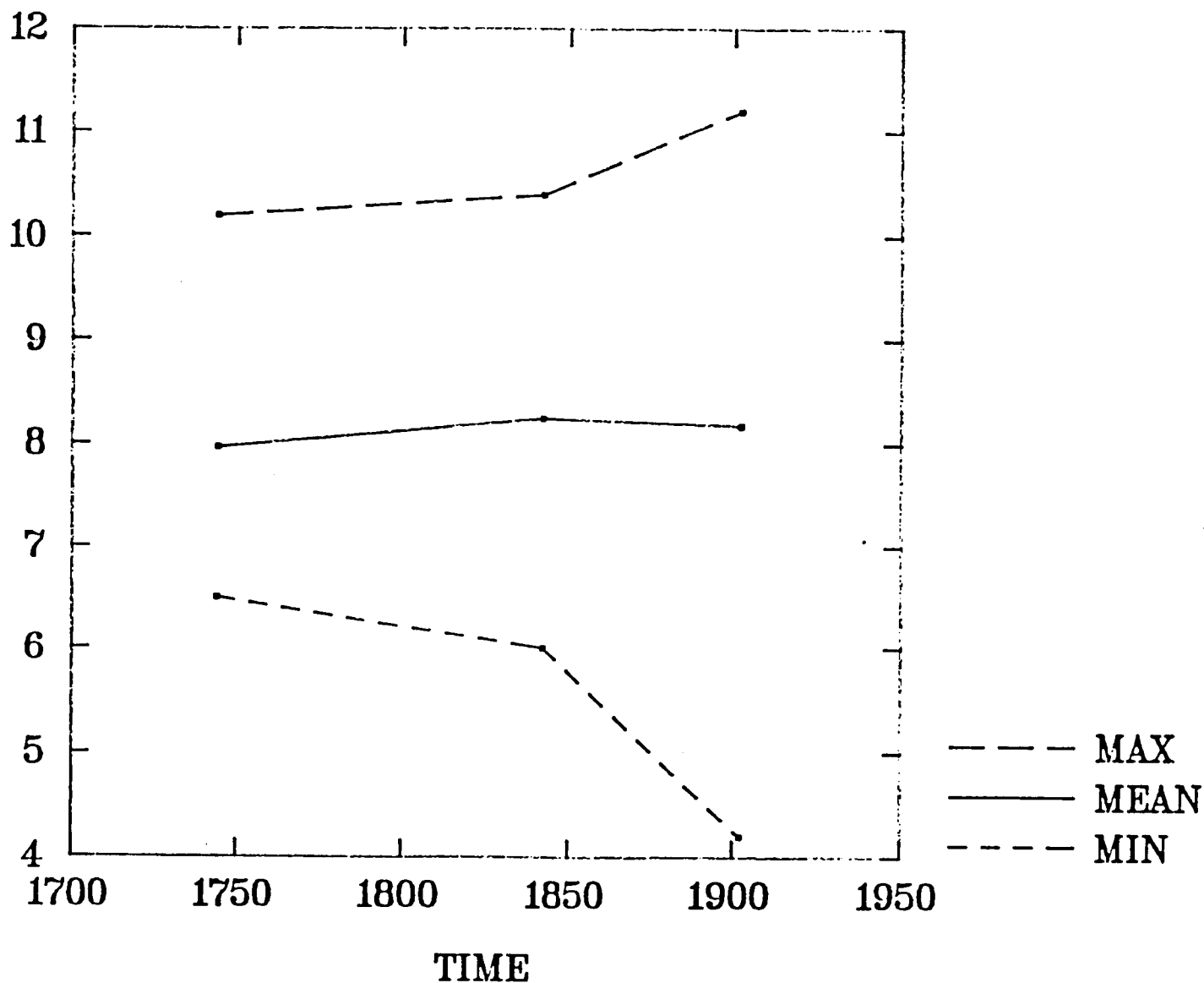


Figure 3-8. Ground Area Apparent Temperature Statistics, 09/10/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the grassy ground area in the image foreground at the single tree site are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43 and 49.

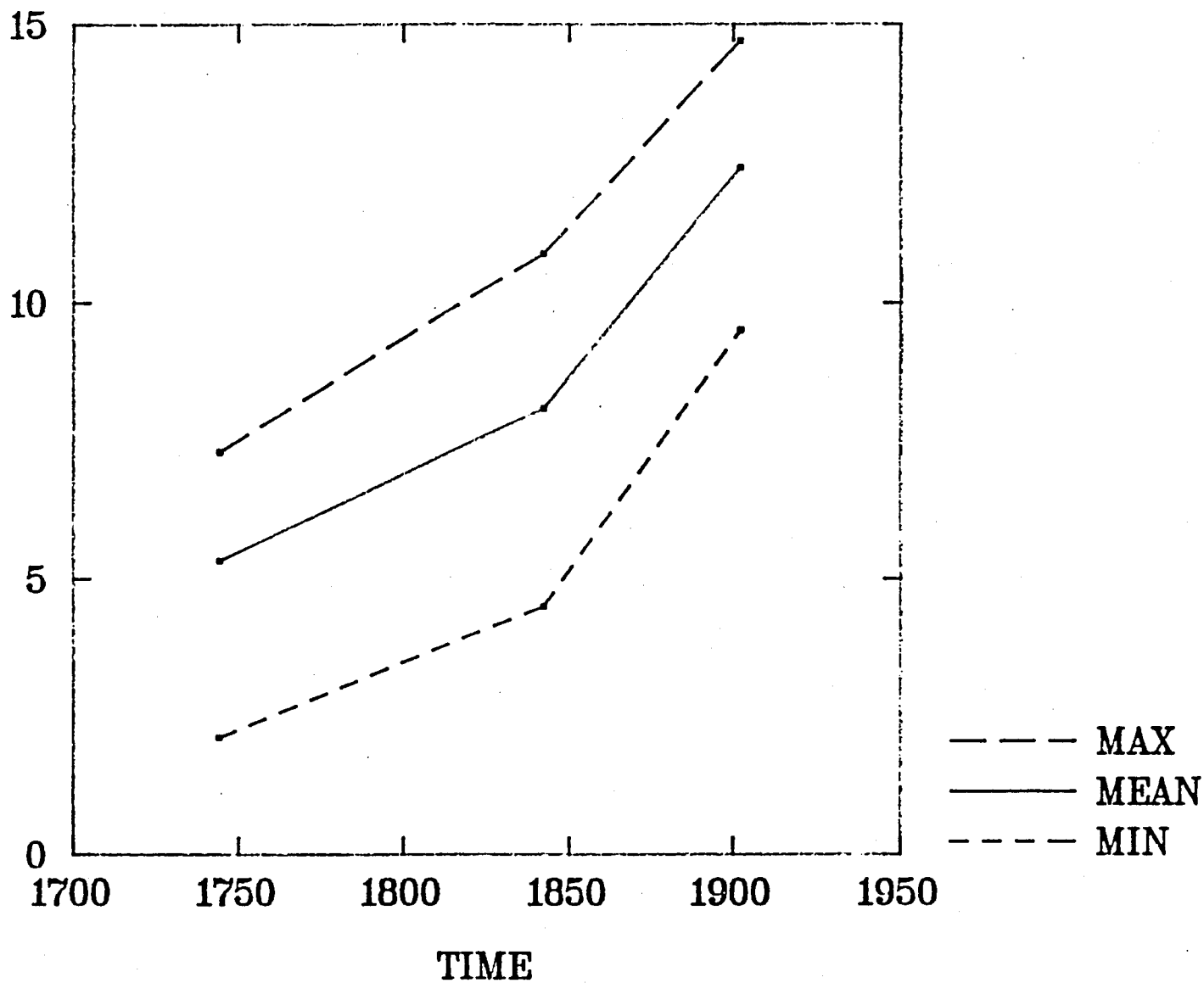


Figure 3-9. Foreground Brush Apparent Temperature Statistics, 09/10/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the brush in the image foreground, lower right corner, at the single tree site are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43, and 49.

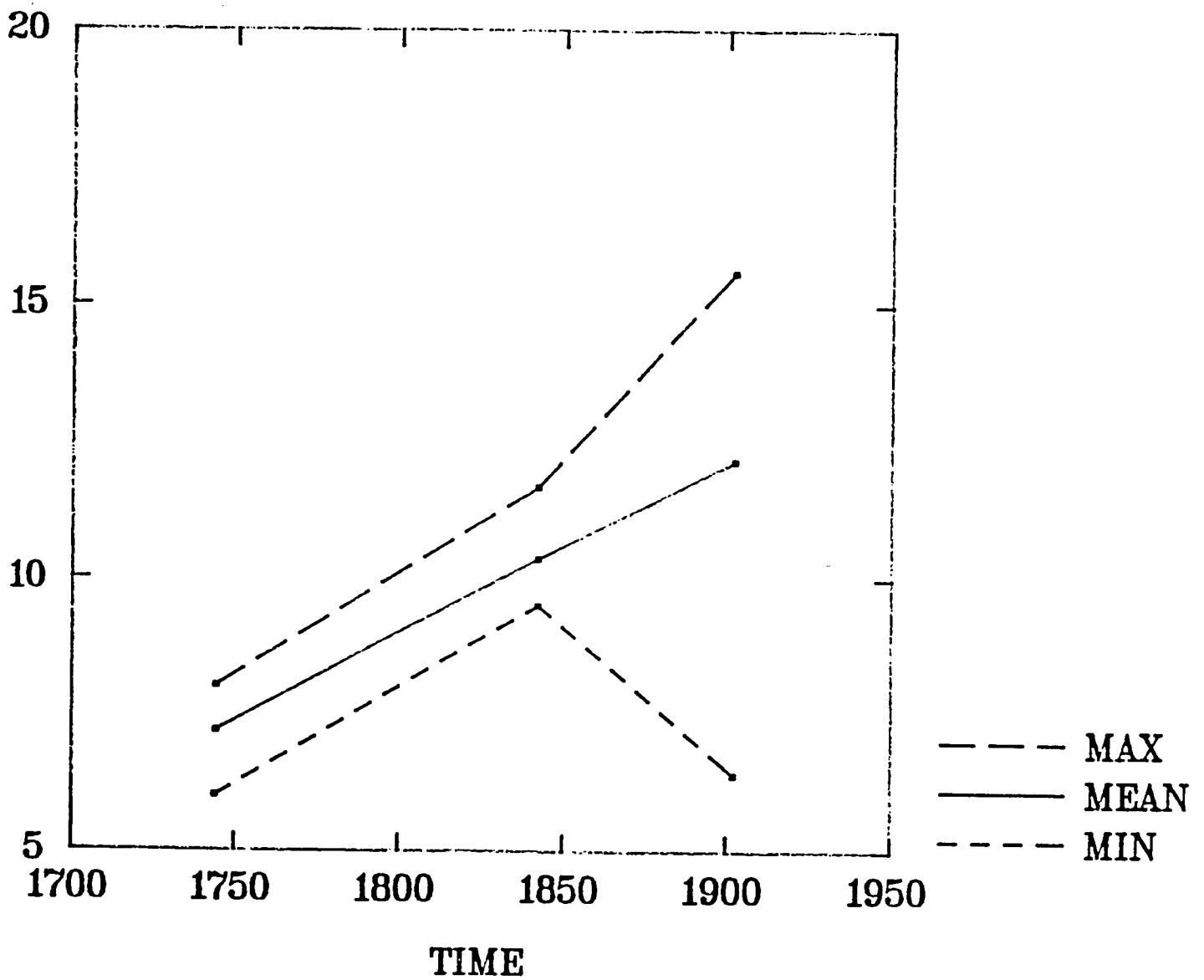


Figure 3-10. Leaf Area Apparent Temperature Statistics, 09/10/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43, and 49.

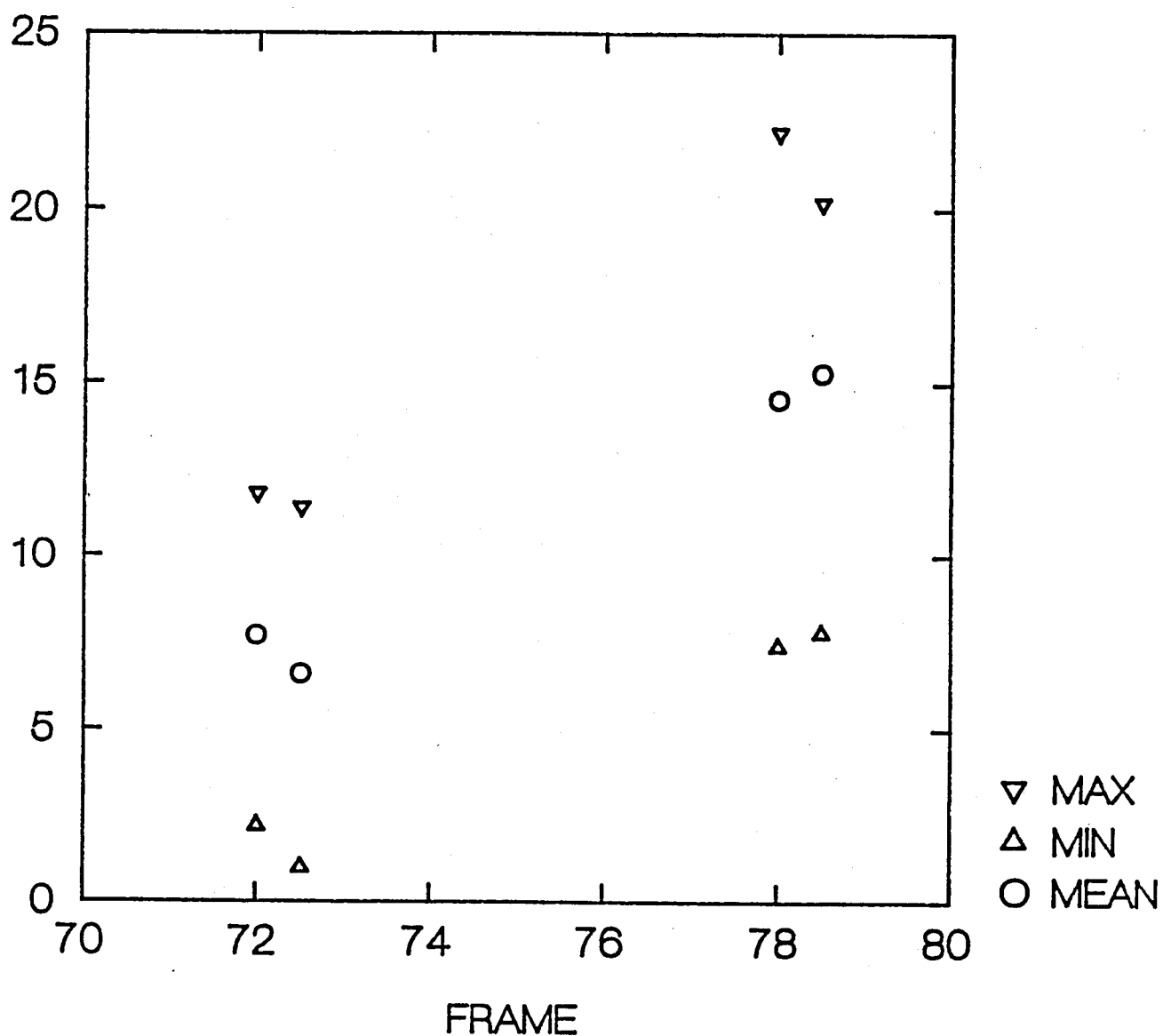


Figure 3-11. Leaf Area Apparent Temperature Statistics, 09/11/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for pairs of images obtained during time periods with variable cloud cover on 11 September, 1990. Leaf area is on center/right portion of imaged tree crown, and has good southern exposure. Image pairs are taken from frames 72 and 78.

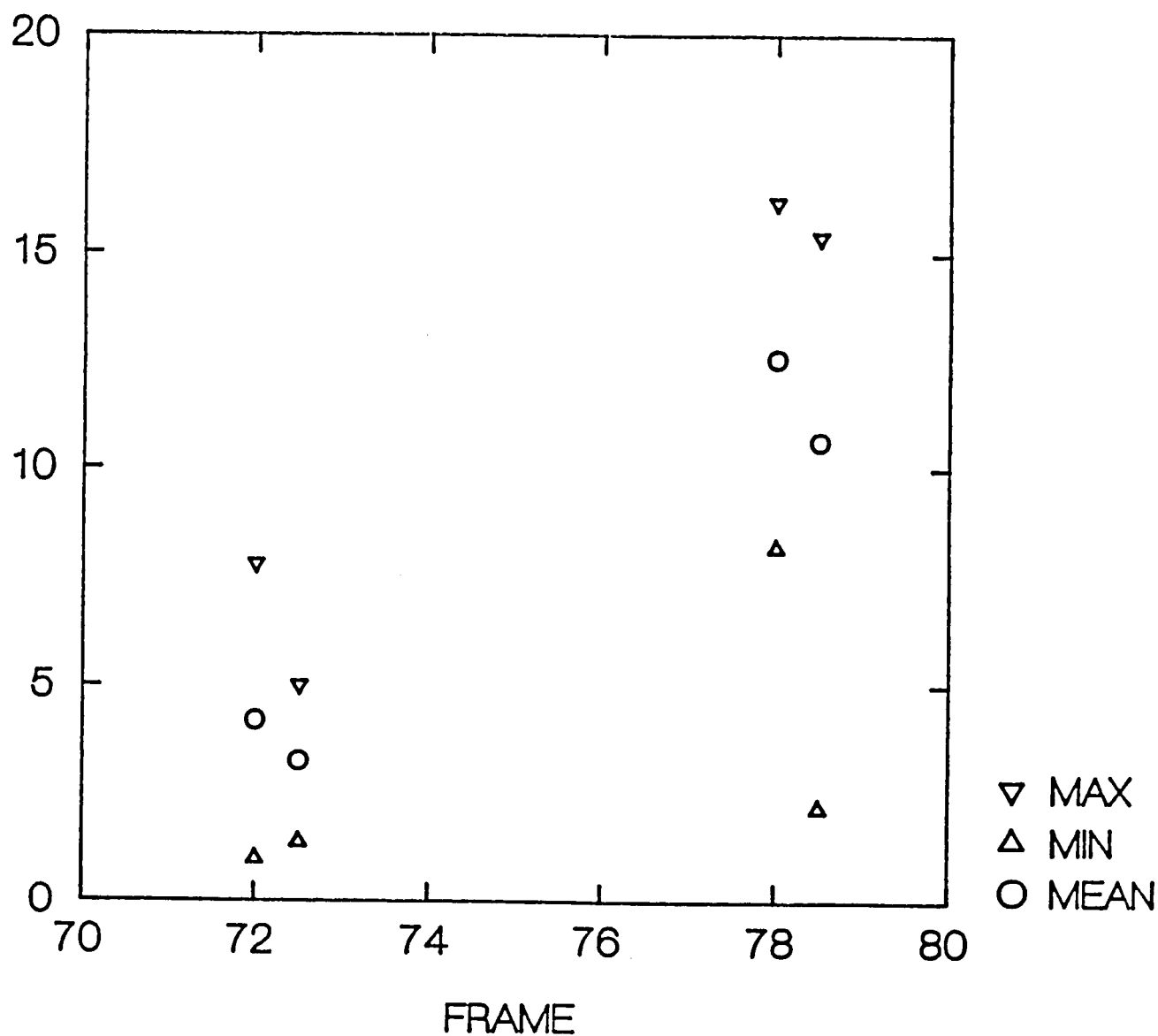


Figure 3-12. Second Leaf Area Apparent Temperature Statistics, 09/11/90

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for pairs of images obtained during time periods with variable cloud cover on 11 September, 1990. Leaf area is on left portion of imaged tree crown, with more northern exposure. Image pairs are taken from frames 72 and 78.

Appendix C

Standard Scenes Database

SUBJECT: Imagery Database and Supplementary Information

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C.1. Background on Standard Scenes

A database on six Standard Scenes was developed for the U.S. Army Tank-Automotive Command (TACOM) by the Keweenaw Research Center (KRC). Background information on the Standard Scenes program at KRC can be obtained in the U.S. Army Tank-Automotive Command Research, Development and Engineering Center Technical Report No. 13482, "Standard Scenes Program for Establishing a Natural Scenes Data Base", by W. R. Reynolds, A. M. L. LaHaie, and R. K. Baratono (1989). Content and formats of files in the Standard Scenes database are summarized in the following sections. Table C.1. provides an overview of the contents of the Standard Scenes database.

C.2. Elevation data

C.2.1. Data Format. The topography of each Standard Scene is presented in contour maps and cross-sectional elevation maps. Contour maps are shown in Figures C.1 through C.6. Elevation data for the field containing the areas designated as Standard Scenes I, II, and III, respectively, also have been described in terms of a grid with the following specifications:

- o resolution = 10 meters (m), i.e., elevation values are given for points every 10 m in the x- and y-directions
- o magnetic North lies in positive direction of y-axis
- o approximate dimensions of the field are: 370 m wide (east-west, or x-direction), and 470 m long (north-south, or y-direction)

Two separate files, each of which contains complete elevation data, are provided. These files differ in format and in the amount of supplementary information provided; you may find one format preferable over the other for your purposes.

C.2.1. ELEV.DAT Elevation Data File. This file contains a 38x48 matrix of elevation values. Each element in the matrix represents the elevation at an intersection point in the (10 m resolution) grid overlay of the field. Element (1,1) in the grid corresponds to the southwestern corner of the field. The image of the field is oriented to coordinate axes in the standard position; thus, element (1,1) is located in the lower left corner of the image.

ELEV.DAT File Format and Description.

Record 1: File identifier, and brief description. Variables in the header, and their format, are as shown on page C-13.

Table C.1: Summary of Standard Scenes Data

SCENE NO.	DATE	TIME	#FRAMES	TARGET
I	11/11-11/12, 1983	1130-1430	85	M60
II	11/15, 1983	1200-1730	14	M60
III	11/15, 1983	1200-1730	5	-
II	11/16, 1983	1000-1700	20	M60
III	11/16, 1983	1000-1700	7	M60
IV	11/17, 1983	1300-2230	24	M60
IV	11/18, 1983	0730-1200	6	M60

Notes: Hourly weather, incomplete solar irradiance data.

II	07/19-07/20, 1984	0700-0800	52	-
III	07/19-07/20, 1984	0700-0800	52	-
I	07/25-07/26, 1984	0600-0600	75	M2-APC
IV	08/01-08/02, 1984	0600-0600	75	M2-APC
V	08/09-08/10, 1984	0600-0600	25	M2-APC

Notes: Right side of M2-APC in Scenes I and IV, Front in Scene V, 48 thermocouples placed on the M2-APC.

I	05/12-05/13, 1985	0800-0700	23	M113-APC
IV	05/14-05/15, 1985	0800-0800	12	M113-APC
V	05/16-05/17, 1985	0700-0700	32	M113-APC
II	05/18-05/19, 1985	0630-0700	32	M113-APC
III	05/19-05/20, 1985	0800-0700	31	M113-APC
VI	05/21-05/22, 1985	0700-0700	18	M113-APC

Notes: Gaps exist in the imagery, 43 thermocouples on the M113-APC.

V	10/21-10/22, 1986	0700-0700	50	M113-APC
IV	10/23-10/24, 1986	0700-0700	25	M113-APC
II	10/27-10/28, 1986	0600-0600	50	M113-APC
III	10/27-10/28, 1986	0600-0600	25	-
I	10/29-10/30, 1986	0600-0600	50	M113-APC
VI	11/04-11/05, 1986	0600-0600	50	M113-APC

Notes: Local time change from EDT to EST after SS IV test.

Non-Standard Scenes program background sequences (SWB and LWB)

VI	02/16-02/17, 1988	0800-0700	150	M2/M60A3/M151
VI	02/17-02/18, 1988	0800-0800	150	M2/M60A3/M151
VI	02/19, 1988	0800-2321	100	M2/M60A3/M151
Grayling	10/19-10/20 1988	0730-0930	50	M1A1
Grayling	11/03-11/04 1988	0700-0930	50	M1A1

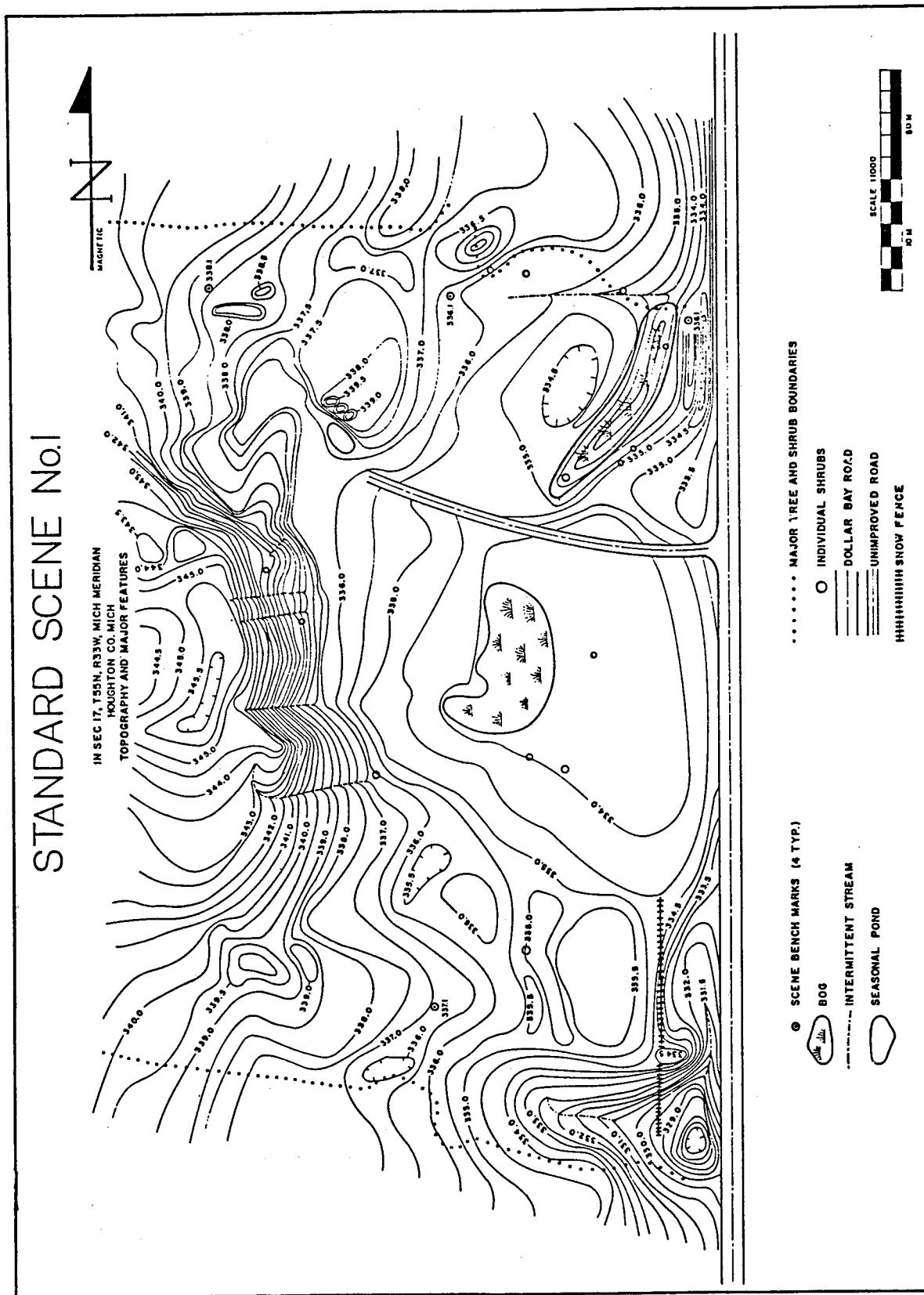


Figure C.1: Topographical Map of Standard Scene 1

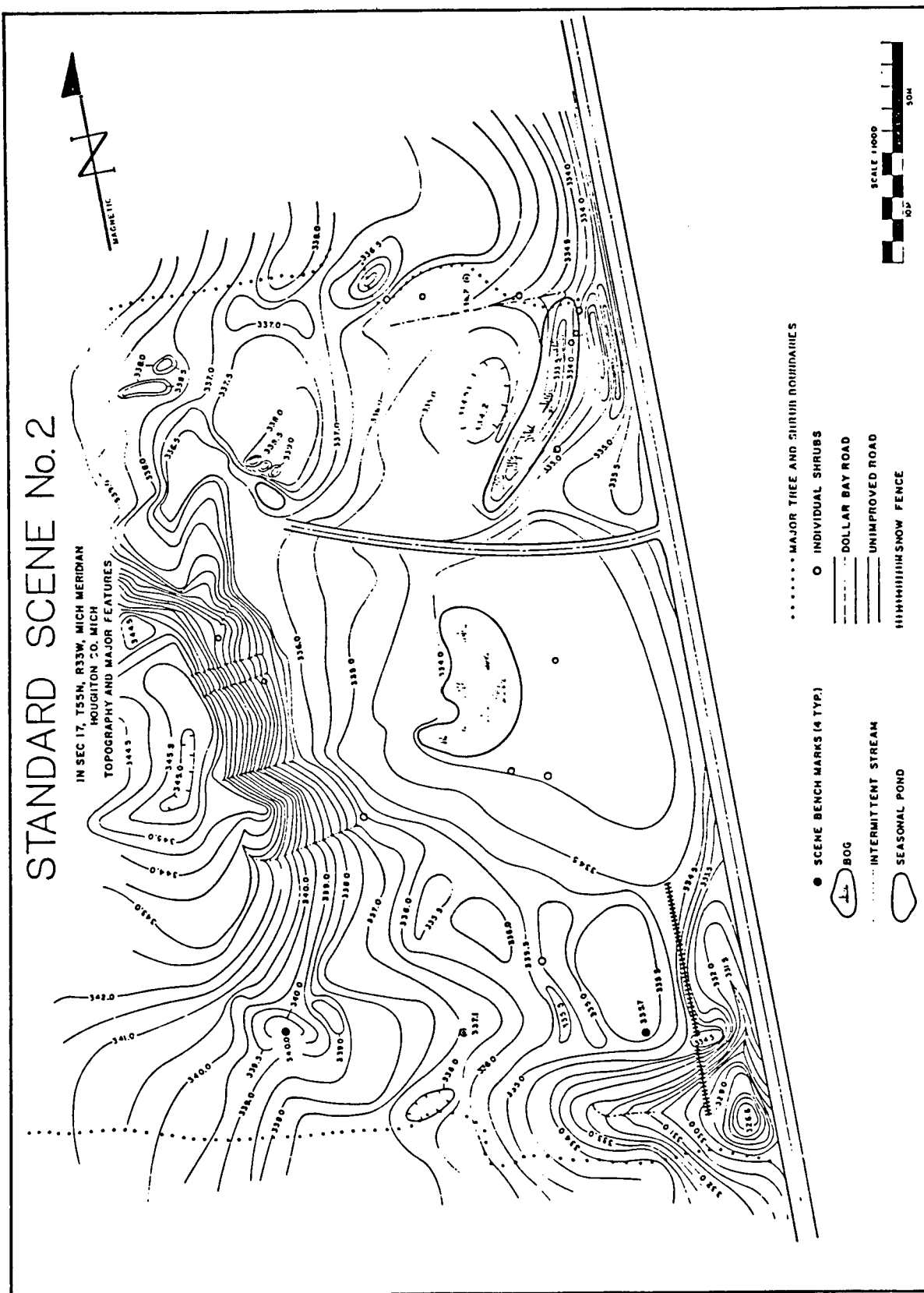


Figure C.2: Topographical Map of Standard scene II

STANDARD SCENE No. 3

IN SEC17, T35N, R33W, MICH MERIDIAN
HOUGHTON CO. MICH
TOPOGRAPHY AND MAJOR FEATURES



- SCENE BENCH MARKS (4 TYR)
- BOG
- INTERMITTENT STREAM
- SEASONAL POND
- MAJOR TREE AND SHRUB BOUNDARIES
- INDIVIDUAL SHRUBS
- DOLLAR BAY ROAD
- UNIMPROVED ROAD



Figure C.3: Topographical Map of standard Scene III

IN SEC 16, T55N, R33W MICH. MERIDIAN
HOUGHTON CO. MICH.



Figure C.4: Topographical Map of Standard Scene IV

IN SEC 16, T55N, R33W, MICH. MERIDIAN
HOUGHTON CO. MICH.

TOPOGRAPHY AND MAJOR FEATURES

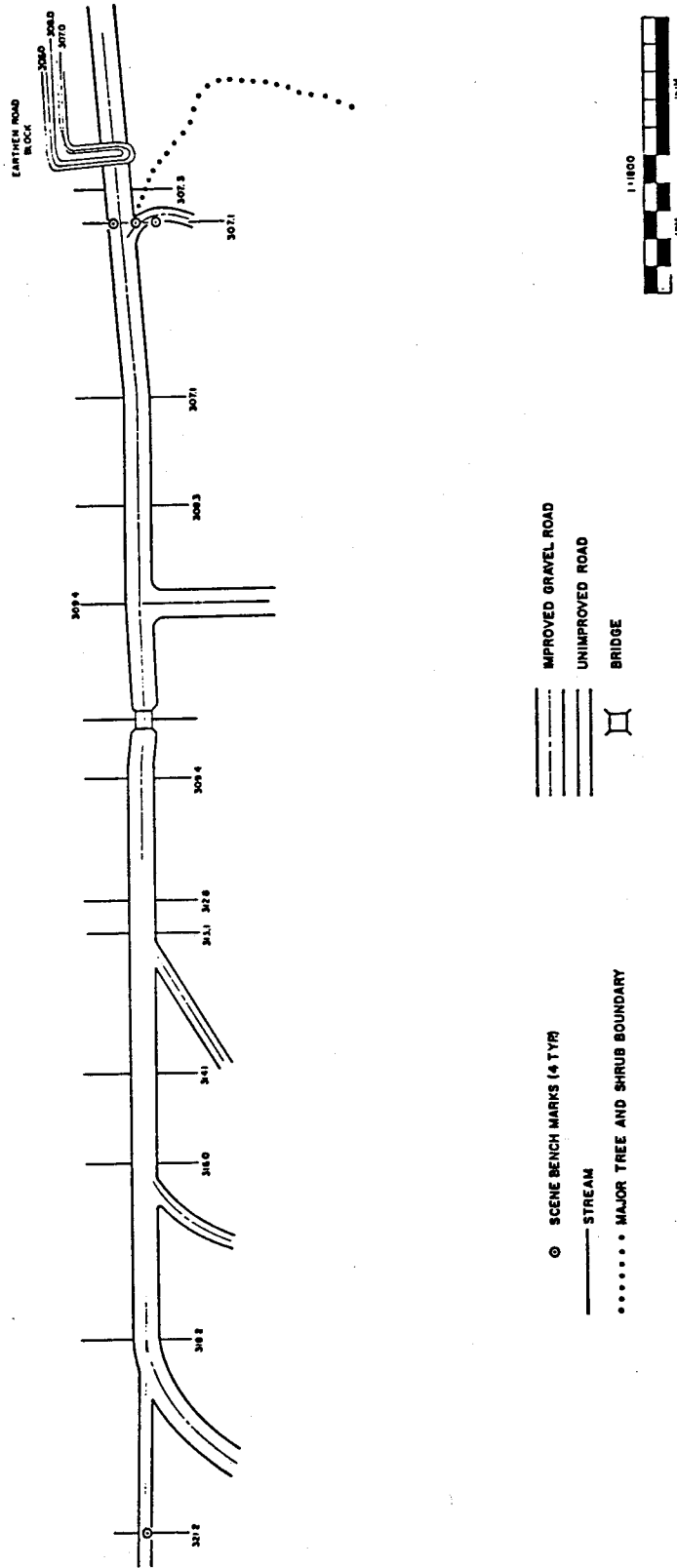


Figure C.5: Topographical Map of Standard Scene V

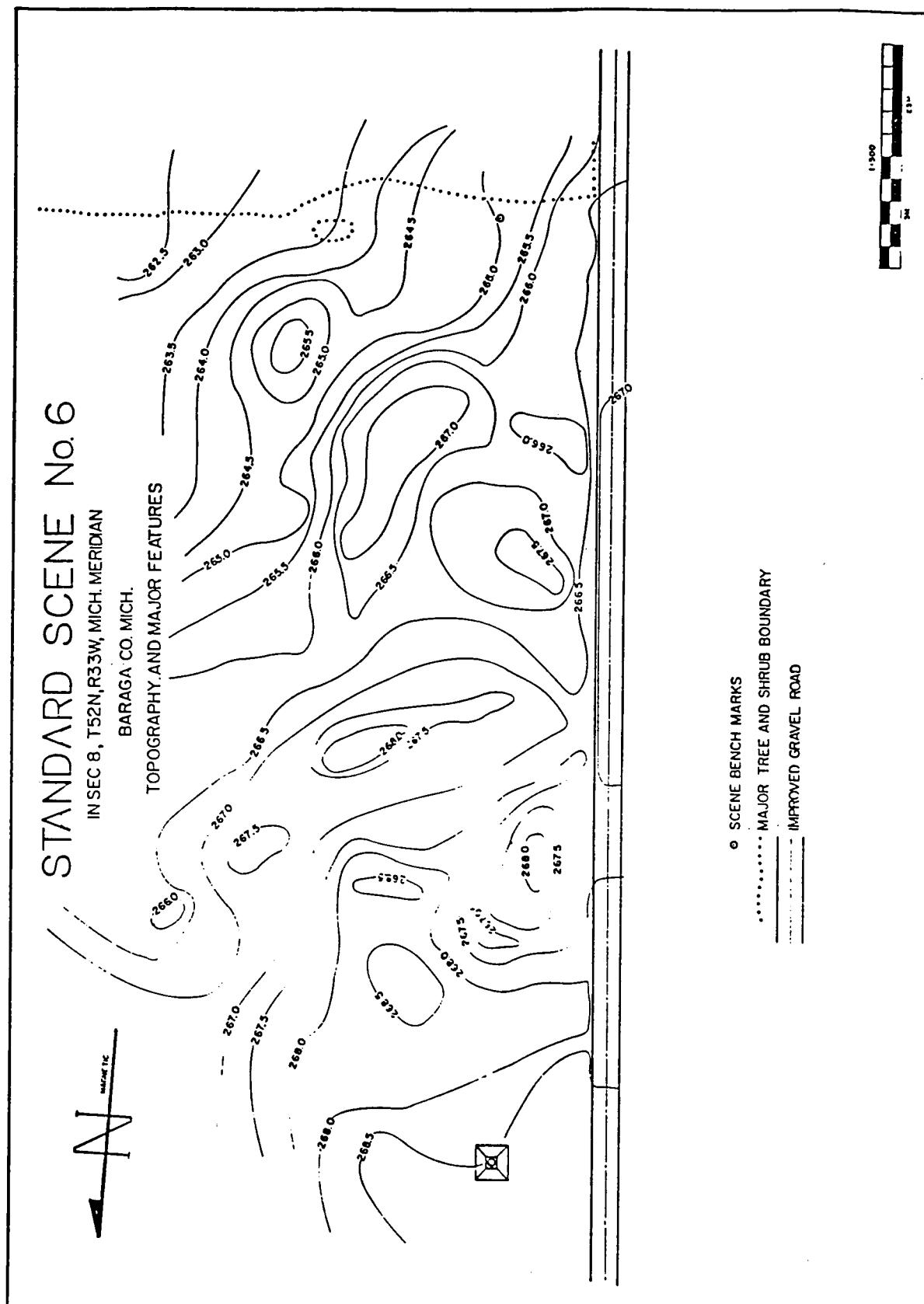


Figure C.6: Topographical Map of Standard Scene VI

(File format, Record 1 of ELEV.DAT File)

FILEID, SITEID, QUAD, N, M, UNITS, XSPACE, YSPACE, ZSCALE,
LAT, LONG

FORMAT(1X, '\$\$', I2, 1X, A10, 1X, I1, 1X, 2I4, 1X, A7, 3F5.0, 2F7.2).

<u>Variable</u>	<u>Definition</u>
FILEID	Identify file as elevation matrix (= 11)
SITEID	Identify site that file describes
QUAD	Image quadrant: 1 : x increases to right, y to top 2 : x increases to left, y to top 3 : x increases to left, y to bottom 4 : x increases to right, y to bottom
N	Number of rows in elevation grid
M	Number of columns in elevation grid
UNITS	Units used for grid spacing
XSPACE	X direction grid spacing, in given units
YSpace	Y direction grid spacing, in given units
ZSCALE	Z scale; 1 unit change in input data value value = ZSCALE units change in given units
LAT	Site latitude, in degrees
LONG	Site longitude, in degrees

For example, the heading for the ELEV.DAT file describing the site of KRC Standard Scenes 1, 2, and 3 reads as follows:

__\$11_KRC_S1,2,3_1_ 38 48_METERS_ 10.0 10.0 1.00 47.175 88.492

The following records in ELEV.DAT give NxM elevation values Z(I,J) beginning with those in row I=1, e.g.,

Z(I,1), Z(I,2), Z(I,3), ..., Z(I,M)

Assuming a 38x48 matrix, each of the 38 records would contain 48 values - Z(I,1) to Z(I,48) - and would be written on six lines, with

FORMAT(5(9(1X,F7.2),/),3(1X,F7.2)).

<u>Variable</u>	<u>Definition</u>
Z(I,J)	Elevation value at (I,J)th point of matrix or grid that overlays site

C.2.2. ELWORLD.DAT Elevation Data File. This file gives a point-by-point description of the site in terms of local coordinates and elevations. For cross-reference purposes, matrix element information corresponding to the grid in file ELEV.DAT is also given. For the site of KRC Standard Scenes

I, II, and III, the location of the origin in local coordinates is within the boundaries of the site, an inconvenience which resulted from selecting the principal surveyor's station (Station A, located along the snow fence in the southeast portion of the field) as the (0,0) point from which all other points would be measured.

ELWORLD.DAT File Format and Description.

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, QUAD, UNITS, XMIN, XMAX, YMIN, YMAX, ZMIN, ZMAX, LAT, LONG

FORMAT(1X,'\$\$',I2,1X,A10,1X,I1,1X,A7,6F5.0,2F7.2).

<u>Variable</u>	<u>Definition</u>
FILEID	Identify file as x,y,elevation data (= 12)
SITEID	Identify site that file describes
QUAD	Image quadrant: 1 : x increases to right, y to top 2 : x increases to left, y to top 3 : x increases to left, y to bottom 4 : x increases to right, y to bottom
UNITS	Units used for X, Y, and Z dimensions
XMIN	Minimum value of X, in given units
XMAX	Maximum value of X, in given units
YMIN	Minimum value of Y, in given units
YMAX	Maximum value of Y, in given units
ZMIN	Minimum value of Z, in given units
ZMAX	Maximum value of Z, in given units
LAT	Site latitude, in degrees
LONG	Site longitude, in degrees

For example, the heading for the ELEV.DAT file describing the site of KRC Standard Scenes 1, 2, and 3 reads as follows:

_\$\$12_KRC_S1,2,3_1_METERS_-350. 20.0-50.0420.0326.8350.3 47.175 88.492

Thus, X ranges from -350 to 20, and Y ranges from -50 to 420. A simple translation of axes using $X' = X + 350.0$ and $Y' = Y + 50.0$ would move the local origin to the southwest corner of the field, thus making the (1,1)th element in the grid the local (X', Y') origin.

Each following record in ELWORLD.DAT gives coordinate values for a single point in the grid. Variables in each record are:

I, J, X, Y, Z(I,J)

FORMAT(2(1X,I3),3(1X,F7.2)).

<u>Variable</u>	<u>Definition</u>
I	Row number of matrix element to which this point corresponds (cf. ELEV.DAT file)
J	Column number of matrix element to which this point corresponds (cf. ELEV.DAT file)
X	X value in local coordinates, given units
Y	Y value, local coordinates, given units
Z(I,J)	Elevation value at (I,J)th point of matrix or grid that overlays site, in given units above sea level.

C.3. Soil Data

C.3.1. Soil Physical and Thermal Characteristics. Soil types present in this site are sand or sand with silt or loam content. A single category of "sand" is adequate to describe the soil at the site. Characteristics are reported along with those for vegetation, in Section C.4.2.

C.3.2. Soil Surface Temperature Distribution. Some data on soil surface temperature distributions could be obtained from bare patches of sand visible in thermal imagery. This is recorded along with information on vegetation class temperature distributions, in Section C.4.3.

C.3.3. Soil Temperature at Various Depths, Across Time. A soil probe was placed on-site during field tests to record soil temperature at various depths. Information on soil temperature for the entire (24-hour) test day is given for each day included in the sample. You may find the entire set of data useful, or simply select the data for the specific time periods that you are modeling. Data is contained in the following files:

<u>File name</u>	<u>Description</u>
T072584.	Standard Scene I, on 25-26 July, 1984
T071984.	Standard Scene II, on 19-20 July, 1984
T071984.	Standard Scene III, on 19-20 July, 1984
T080184.	Standard Scene IV, on 01-02 August, 1984
T080984.	Standard Scene V, on 09-10 August, 1984
T051285.	Standard Scene I, on 12-13 May, 1985
T051885.	Standard Scene II, on 18-19 May, 1985
T051985.	Standard Scene III, on 19-20 May, 1985
T051485.	Standard Scene IV, on 14-15 May, 1985
T051685.	Standard Scene V, on 16-17 May, 1985
T052185.	Standard Scene VI, on 21-22 May, 1985
T102986.	Standard Scene I, on 29-30 October, 1986
T102786.	Standard Scene II, on 27-28 October, 1986
T102786.	Standard Scene III, on 27-28 October, 1986
T102386.	Standard Scene IV, on 23-24 October, 1986
T102186.	Standard Scene V, on 21-22 October, 1986
T110486.	Standard Scene VI, on 04-05 November, 1986

Tnnnnnn. Soil Temperature File Format and Description.

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, DATE, UNITS

FORMAT(1X,'\$\$',I2,1X,A10,1X,I6,1X,A7).

<u>Variable</u>	<u>Definition</u>
FILEID	Identify file as soil temp data (= 13)
SITEID	Identify site that file describes
DATE	Month, Day, and Year (MMDDYY) of test
UNITS	Units of Measure for temperature

Each following one-line record gives data for one time period, in the following format:

TIME, TSURF, T1, T5, T10, T20, T50

FORMAT(I4,6(2X,F7.3))

<u>Variable</u>	<u>Definition</u>
TIME	Time at which soil temp measurements are taken. Interval between readings is 5 min.
TSURF	Soil Temperature at Surface
T1	Soil Temperature at 1 cm depth
T5	Soil Temperature at 5 cm depth
T10	Soil Temperature at 10 cm depth
T20	Soil Temperature at 20 cm depth
T50	Soil Temperature at 50 cm depth

C.4. Vegetation Data

C.4.1. Vegetation Class Maps. Information about the types of vegetation occurring in each scene is summarized on vegetation maps on same scale as topographic maps.

Vegetation Types and Classification Codes. Types of vegetation are listed below, along with the corresponding classification codes (cf. the ARTBASS codes).

<u>Ground Cover</u>	<u>Code</u>
Grass	2
Wooded	6
Shrub	10
Bog	12
Moss	15
Sand (bare)	36

Note more detailed plant survey information about type and percent ground cover of vegetation in, e.g., moss-dominated portions of the field is available if desired.

C.4.2. Vegetation Class Physical and Thermal Characteristics. Typical values for a variety of class properties are given in the table below. Where only one value is given, it may be interpreted as the typical, or average, value; otherwise, the pair of values represent the range of typical values.

Table of Vegetation and Soil Characteristics.

Typical values or ranges of typical values are shown.

<u>TYPE</u>	<u>MEASURE</u>	<u>MIN.</u>	<u>MAX.</u>	<u>UNITS</u>
NORTHWAY FINE				
SAND	SPECIFIC HEAT	1100		J/kg-°K
"	EMISSIVITY	0.92		
"	ABSORPTIVITY	0.60		
" - DRY	DENSITY	1759		kg/m ³
" - DRY	CONDUCTIVITY	0.40		W/m-°K
" - WET	CONDUCTIVITY	1.08		W/m-°K
SANDY SOIL	ALBEDO	0.25		
FOLIAGE	ABSORPTIVITY	0.74		
FOLIAGE	EMISSIVITY	0.94	0.96	
MOSS	HEIGHT	0.01		m
MOSS	DENSITY	14.0		patches/m ²
MOSS	ALBEDO	0.10		
GRASS	HEIGHT	0.20		m
DRY GRASS-SUN	ALBEDO	0.15	0.25	
DRY GRASS	ALBEDO	0.19	0.22	
WET GRASS-SUN	ALBEDO	0.33	0.37	
WET GRASS	ALBEDO	0.14	0.26	
SHRUB	HEIGHT	0.12	0.30	m
SHRUB	DENSITY	15.0		patches/m ²
SHRUB	LEAFLENGTH	0.05	0.06	m
SHRUB	LEAFWIDTH	0.03		m
SHRUB-LIVE	EMISSIVITY	0.95		
SHRUB-DORMANT	EMISSIVITY	0.94		
BOG	HEIGHT	0.20	0.42	m
BOG	DENSITY	1548		patches/m ²
TREE-POPULUS	HEIGHT	12.0	16.0	m
TREE-PINUS	HEIGHT	14.0	17.0	m
TREE-ACER	HEIGHT	11.0	14.0	m
TREE-QUERCUS	HEIGHT	11.0	14.0	m
TREE-POPULUS	LEAFLENGTH	0.07	0.12	m
TREE-POPULUS	LEAFWIDTH	0.04	0.10	m
TREE-ACER	LEAFLENGTH	0.15		m
TREE-ACER	LEAFWIDTH	0.15		m
TREE-QUERCUS	LEAFLENGTH	0.12		m
TREE-QUERCUS	LEAFWIDTH	0.08		m

C.4.3. Vegetation Class Temperature Distributions. Temperature information on the various vegetated areas in each Standard Scene were obtained by processing thermal imagery taken at the designated times, and calculating statistics from it. It was not possible to obtain data for all vegetation classes included on the maps by this method, so you will have to use your empirical background to supplement the data provided.

CLASS Temperature Data File Names. Class temperature data is contained in files specified by year and by Standard Scene:

<u>File name</u>	<u>Description</u>
CLASS84.SS1	Standard Scene I, on 25-26 July, 1984
CLASS84.SS2	Standard Scene II, on 19-20 July, 1984
CLASS84.SS3	Standard Scene III, on 19-20 July, 1984
CLASS85.SS1	Standard Scene I, on 12-13 May, 1985
CLASS85.SS2	Standard Scene II, on 18-19 May, 1985
CLASS85.SS3	Standard Scene III, on 19-20 May, 1985
CLASS86.SS1	Standard Scene I, on 29-30 October, 1986
CLASS86.SS2	Standard Scene II, on 27-28 October, 1986
CLASS86.SS3	Standard Scene III, on 27-28 October, 1986

Note that the CLASS86.SSn files are not included in the set of files that have just been sent. They or alternate files will be provided as soon as our graphics workstation facilities are available to complete the data processing.

CLASS Temperature File Format and Description.

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, DATE, UNITS

FORMAT(1X,'\$\$',I2,1X,A10,1X,I6,1X,A7).

<u>Variable</u>	<u>Definition</u>
FILEID	Identify file as class data (= 14)
SITEID	Identify site that file describes
DATE	Month, Day, and Year (MMDDYY) of test
UNITS	Units of Measure for temperature

Each following one-line record gives data for one time period, in the following format shown on the following page.

FILENAME, TIME, MEAN, STDEV, MAX, MIN, CLASS

FORMAT(F8.3,1X,F4.2,1X,F5.2,1X,F4.2,2(1X,F5.2),1X,I2)

<u>Variable</u>	<u>Definition</u>
FILENAME	KRC archived file reference
TIME	Time period in which temp measurements are taken
MEAN	Average temperature for CLASS, this time
STDEV	Temperature standard Deviation for CLASS, this time period
MAX	Maximum temperature for CLASS, this time
MIN	Minimum temperature for CLASS, this time
CLASS	ARTBASS classification code for vegetation or soil type that is described by the preceeding statistics
	<u>Ground Cover Code</u>
	Grass 2
	Wooded 6
	Shrub 10
	Bog 12
	Moss 15
	Sand (bare) 36

C.5. Weather Data

C.5.1. Data on Selected Weather Parameters, Across Time. Information on selected weather parameters for the entire (24-hour) test day is given for each day included in the sample. You may find the entire set of data useful, or simply select the data for the specific time periods that you are modeling.

C.5.2. Weather File Names. Complete data on selected weather parameters, measured at 5-minute intervals throughout the test day are contained in the following files. Summary descriptions of day and nighttime conditions are included.

<u>File name</u>	<u>Description</u>
W072584.2	Standard Scene I, on 25-26 July, 1984 Warm, sunny day with few clouds Clear night
W071984.2	Standard Scene II, on 19-20 July, 1984 Warm, sunny day; high solar loading Clear night
W071984.2	Standard Scene III, on 19-20 July, 1984 Warm, sunny day; high solar loading Clear night
W080184.2	Standard Scene IV, on 01-02 August, 1984 Dense fog in AM, overcast in PM Foggy night
W080984.2	Standard Scene V, on 09-10 August, 1984 Partly cloudy, warm day Partly cloudy night
W051285.2	Standard Scene I, on 12-13 May, 1985 Mostly overcast, windy day; some rain Rain at night; clearing toward morning

W051885.2 Standard Scene II, on 18-19 May, 1985
Clear day, light cirrus
Clouds toward morning, rain developing

W051985.2 Standard Scene III, on 19-20 May, 1985
Partly cloudy day, clearing in PM
Clear night

W051485.2 Standard Scene IV, on 14-15 May, 1985
Overcast, low clouds, clearing in PM
Mostly clear night, light rain at 0500

W051685.2 Standard Scene V, on 16-17 May, 1985
Cloudy, cold, windy; rain in early PM
Clear night

W052185.2 Standard Scene VI, on 21-22 May, 1985
Clear day, light cirrus in early PM
Clear night

W102986.2 Standard Scene I, on 29-30 October, 1986
Overcast day, occasional snow flurries
Clear after midnight

W102786.2 Standard Scene II, on 27-28 October, 1986
Mostly clear day
Dense fog at night

W102786.2 Standard Scene III, on 27-28 October, 1986
Mostly clear day
Dense fog at night

W102386.2 Standard Scene IV, on 23-24 October, 1986
Overcast day
Mostly cloudy night, clearing by 0300

W102186.2 Standard Scene V, on 21-22 October, 1986
Clear day, light cirrus
Clear night, light haze early

W110486.2 Standard Scene VI, on 04-05 November, 1986
Partly cloudy AM, clearing in late PM
Mostly cloudy night

Weather File Format and Description.

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, DATE

FORMAT(1X,'\$\$',I2,1X,A10,1X,I6).

<u>Variable</u>	<u>Definition</u>
FILEID	Identify file as weather data (= 04)
SITEID	Identify site that file describes
DATE	Month, Day, and Year (MMDDYY) of test

Each following one-line record gives data for one time period, in the following format:

TIME, AIRT, SOLAR, WIND, HUMID, HUMID, CLOUD

FORMAT(I4,5F9.0).

<u>Variable</u>	<u>Definition</u>
TIME	Time at which soil temp measurements are taken. Interval between readings is 5 min.
AIRT	Air temperature in °Celsius
SOLAR	Solar irradiance in Watts/M ²
WIND	Wind speed in M/sec
HUMID	Relative humidity in percent (0 - 100)
CLOUD	Cloud cover, tenths (0=clear, 10=overcast)

C.6. Thermal Imagery of Standard Scenes

C.6.1. Thermal Imagery Data Files. Thermal images of each Standard Scene were taken hourly throughout the 24-hour time periods described in the "Weather" section. In some cases, additional imagery of various vehicles was also recorded, as summarized in Table C.1.

Each thermal image is contained in a file specified by Standard Scene number, date (month and year) it was recorded, and a frame number. The names of these files are in the format "S#MOYR.FRM, where "S#" states the Scene number, "MOYR" is the month and year in which the frame was recorded, and "FRM" is the frame number assigned to that image. For example, the file named "S11086.234" contains the thermal image of Standard Scene I, taken during October, 1986, with frame number 234.

Thermal Imagery File Format and Description.

Record 1: File identifiers, and brief description. Variables in the header, and their format are:

FRAMENO,DATE,TIME,DESCRIB,RANGE

FORMAT(5X,I5,11X,I6,1X,I4,6X,A20,5X,I4).

where:

<u>Variable</u>	<u>Definition</u>
FRAMENO	Frame number assigned to image
DATE	Month, day, year (MMDDYY) of test
TIME	Time of day (24-hour clock)
DESCRIB	Brief description of image contents
RANGE	Temperature range (°C). Common values are 2, 5, 10, 20, 50, 100, or 200°C.

The remaining records in the file give line-by-line data on pixel temperatures, in a 128x128 pixel format for files from 1984 and 1986, and in a 256x256 pixel format for files from 1985. The format of the pixel apparent temperature data is given by the statements that follow:

PTEMP(I,J)

FORMAT(M(K(16I5,/)))

where I=1,2,...,N

N=128 for 1984 and 1986 files

N=256 for 1985 files

J=1,2,...,M

M=128 for 1984 and 1986 files

M=256 for 1985 files

K=N/16

and

<u>Variable</u>	<u>Definition</u>
-----------------	-------------------

PTEMP(I,J)	Temperature of the pixel in i th row, j th column of the image. Value is stated as: (°K.) * 10.
------------	--

Image rows and columns are numbered as in matrix notation, beginning in the upper left-hand corner of the image as it is viewed on the screen. A pixel value of PTEMP(I,J)=0 indicates a border pixel, not an element of the image.

Appendix D

Scene Metrics with “SCENEMEZ” Software

Texture Segments and Texture Metrics
Calculated from Standard Scenes Imagery

January, 1991

Keweenaw Research Center
Michigan Technological University
Houghton, Michigan

1.0 INTRODUCTION

The following is a summary report describing work performed at the Keweenaw Research Center (KRC) to generate scene metrics as part of Smart Weapons Operability Enhancement (SWOE) Program. The infrared imagery used for this purpose is described, and the image texture segments obtained from this imagery are detailed. The KRCMEZ program used to generate texture statistics is briefly described in Section 3.

2.0 IMAGERY AND TEXTURE SEGMENT FILES

Imagery for which scene metrics were generated was originally obtained during a 1986 field test performed at the Keweenaw Research Center (KRC) Standard Scene VI, located in the northern portion of Michigan's Upper Peninsula. Figures 1.1, 1.2, and 1.3 depict the topography, elevation (cross-sectional view), and general vegetation features, respectively, of Standard Scene VI. Imagery was obtained from the vantage of a 30 meter tower using an AGA thermal imager operating in the 8-12 um band.

The foreground of Standard Scene VI consists of a uniform field of tall grasses and clover. The treeline at the edge of this field is predominantly deciduous along the south face. The centerline viewing direction is set at 175.4° from north.

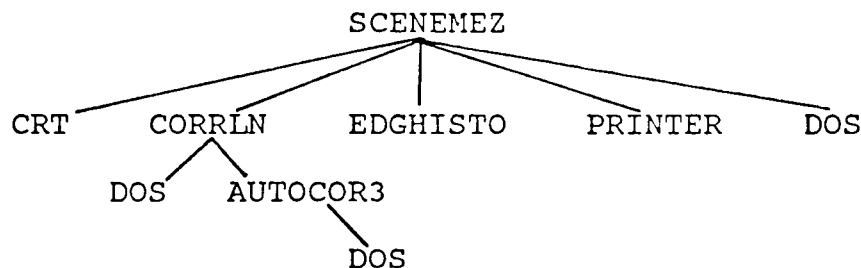
An area at the far end of the field was imaged once each hour for 24 consecutive hours. This imagery was digitized and converted to temperature frames (see Reynolds, et al., 1989). The field test took place 04-05 November, 1986, so trees are bare of leaves and the grass is dry and brown. It should be noted that images from early morning hours (0300-0500) contain very little actual temperature differentiation: apparent variations of temperature in these images are more significantly indicative of noise than are images from other time periods in the day.

For the purpose of generating scene metrics, two texture areas were sampled from each image: trees in the treeline, and tall grass in the open field in the foreground. Texture segment files in the necessary format were generated by processing binary image files through the KRC "os7" image processing software.

Standard Scene VI imagery was selected for inclusion in this work principally because of the depression angle afforded by viewing the scene from a tower. The 1986 diurnal sequence of imagery was particularly appropriate because all input data was available in the format required by the SCENEMEZ scene metrics program. Thermal imagery obtained by KRC during its participation in the 1990 Forest Ecosystem Dynamics Multisensor Aircraft Campaign (FED MAC) Experiment in Howland, Maine, is also well suited to this application and scene metrics are presently being generated from this data.

3.0 COMMENTS ON KRCMEZ PROGRAM

The KRCMEZ program is a variation of the SCENEMEZ program, the complete unit structure of which is shown below:



where crt, dos, and printer are standard units of Turbo Pascal 5.0; corrln, edghisto and autocor3 are units written by Waterways Experiment Station (WES) personnel.

One limitation encountered with the original SCENEMEZ.PAS software was that it required use of gray level values as input, and the input of the thermal calibration information. The program then performed its own conversion of gray levels to apparent temperatures. Since most of the imagery generated by KRC has already been converted to frames of apparent temperature values, it was suggested to WES that the program would have wider applicability if it were altered to handle either files of gray level values or files of temperature values. Such a change was introduced in the code for the KRCMEZ.PAS version of this program.

Use of the Pascal programming language may in itself pose something of a limitation. Inasmuch as a great deal of code used on imaging systems is in the C language, it might be worthwhile to convert the entire program to C and thus make it more compatible with related applications.

4.0 DESCRIPTION OF TEXTURE SEGMENT FILES

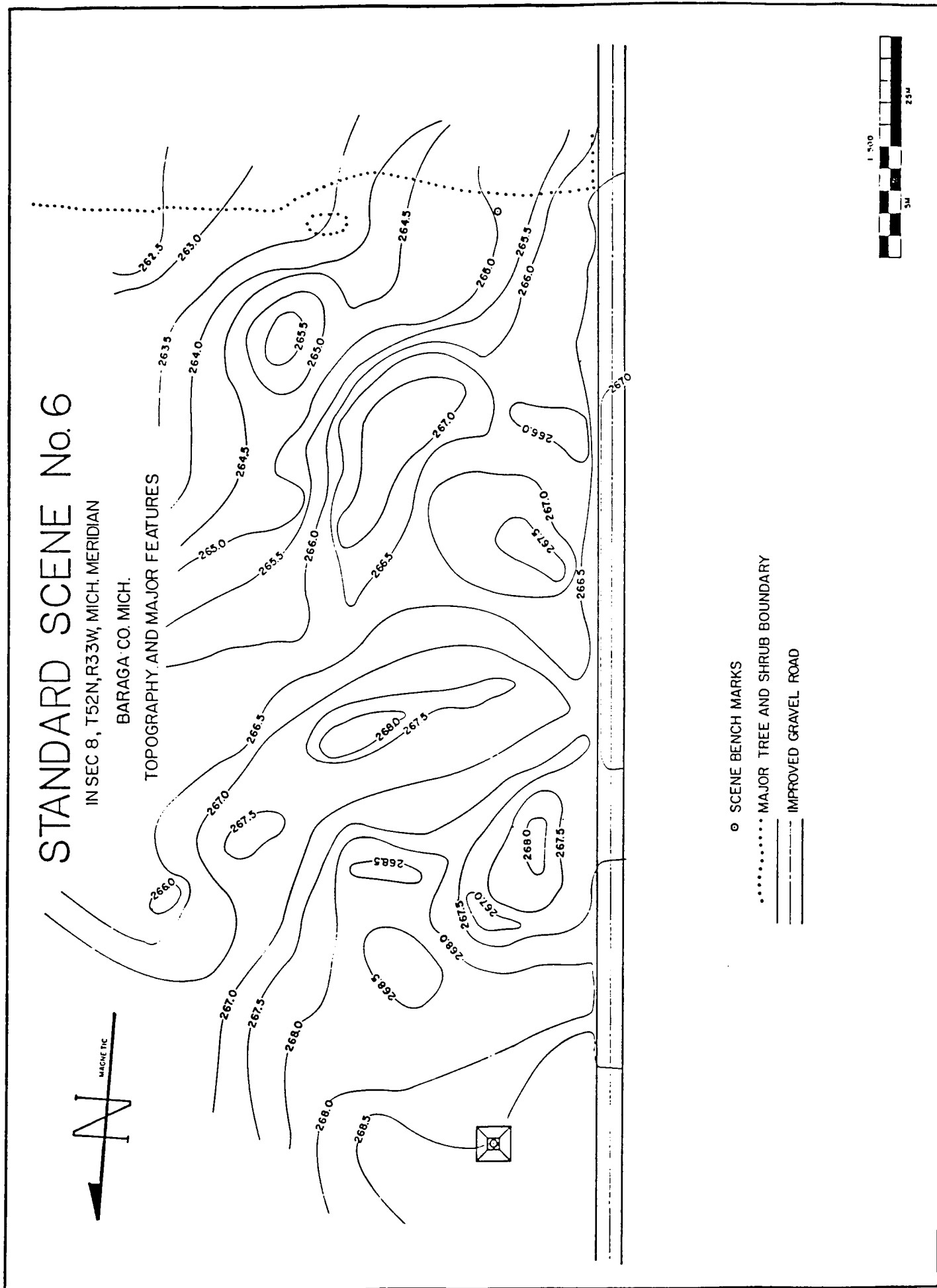
Pertinent information regarding digitized image frames used to create texture segment files is given in Table 4.1. Table 4.2 continues to elaborate the texture segment files, themselves. The information contained in Tables 4.1 and 4.2 represents required inputs to the KRCMEZ program, and details on the definitions of various inputs may be found in the program. Data was obtained from field test logs and digitizing logs, or calculated for specific images and texture segments.

Table 4.3 lists filenames for statistics output files generated for each texture segment. Both the texture segment files and their corresponding output files have been copied onto the accompanying disk. Texture segment data is gray level values from a digitized scale of 0-255. Output statistics are expressed in degrees Celsius.

REFERENCE

William R. Reynolds, Anne Marie L. LaHaie, & Robert K. Baratono, "Standard Scenes Program for Establishing A Natural Scenes Data Base", U.S. Army Tank-Automotive Command RD&E Technical Report No. 13482, Keweenaw Research Center, Houghton, MI, December 1989. (Approved for Public Release: Distribution is Unlimited.)

Figure 1.1 Topographical Map of KRC Standard Scene VI



STANDARD SCENE No. 6

IN SEC 8, T52N, R33W, MICH. MERIDIAN

BARAGA CO. MICH.

CROSS SECTIONAL PROFILE

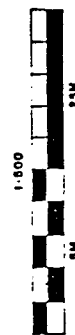
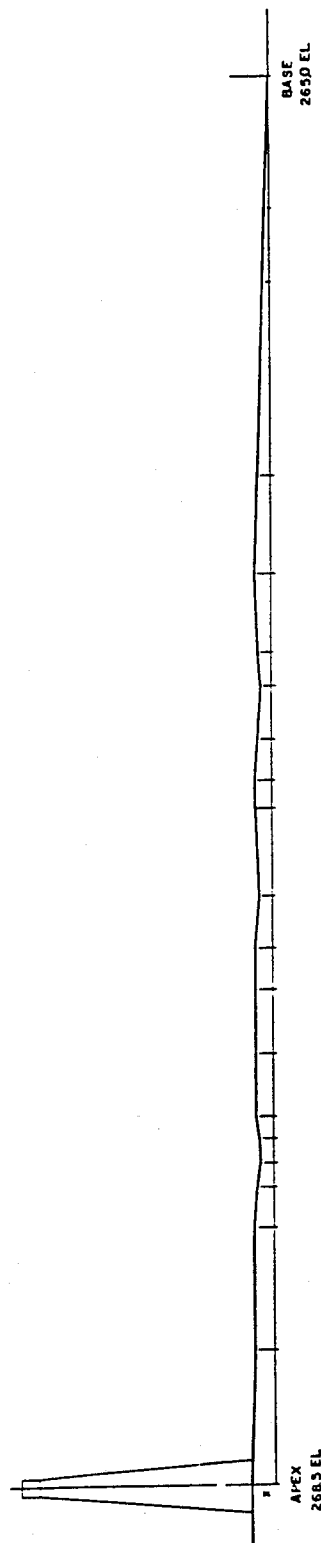
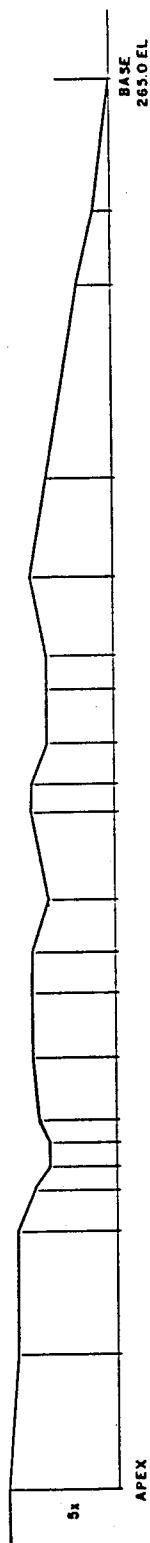


Figure 1.2 Cross-Sectional Elevation Map of KRC Standard Scene VI

Figure 1.1 Vegetation Map of KRC Standard scene VI

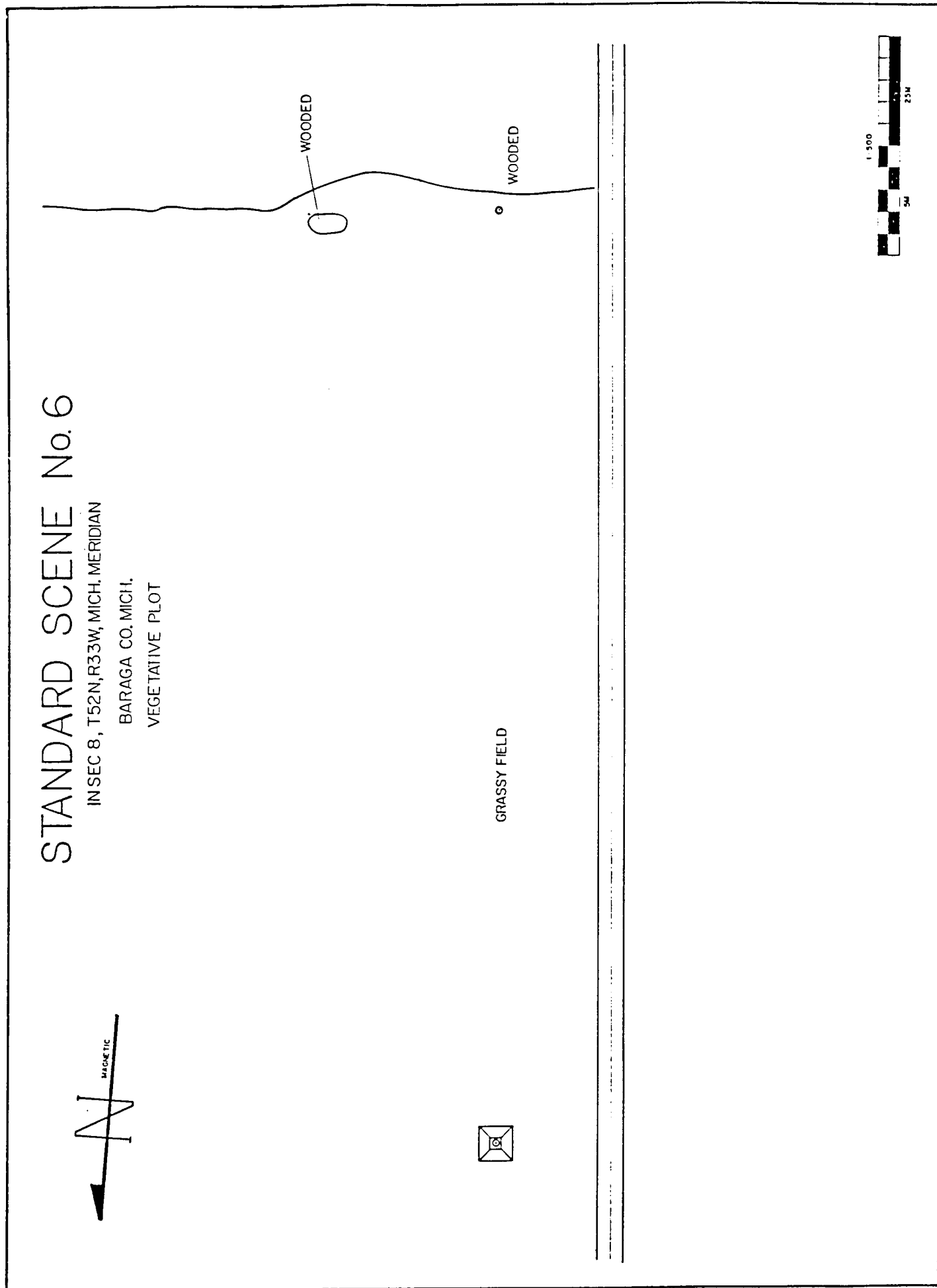


TABLE 4.1 Image Parameter Inputs for Infrared Images

The following data details each of the infrared image files processed by KRC to create texture segment files. Image files are referenced by their frame number, indicated by the "EXT" column below.

Page 1 of 2

EXT	DATE	HOUR	WEATHER			FOV	PIX	AZ	DEP
nnn	mm/dd/yr	hhmm	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	deg	cnt	deg	deg		
001	11/04/86	0600	Broken clouds	0.40	sky cover	8	92	175	7.52
007	11/04/86	0700	Scatter clds	0.60	sky cover	8	92	175	7.52
012	11/04/86	0800	Broken clouds	0.90	sky cover	8	92	175	7.52
017	11/04/86	0900	Overcast	0.95	sky cover	8	92	175	7.52
023	11/04/86	1000	Overcast	0.90	sky cover	8	92	175	7.52
028	11/04/86	1100	Broken Clouds	0.85	sky cover	8	92	175	7.52
035	11/04/86	1200	Broken clouds	0.80	sky cover	8	92	175	7.52
041	11/04/86	1300	Broken clouds	0.25	sky cover	8	92	175	7.52
047	11/04/86	1400	Scatter clds	0.15	sky cover	8	92	175	7.52
053	11/04/86	1500	Clear	0.00	sky cover	8	92	175	7.52
059	11/04/86	1600	Clear	0.00	sky cover	8	92	175	7.52
061	11/04/86	1603	Clear	0.00	sky cover	8	92	175	7.52
067	11/04/86	1700	Clear	0.00	sky cover	8	92	175	7.52
073	11/04/86	1800	Clear	0.00	sky cover	8	92	175	7.52
081	11/04/86	1900	Clear	0.00	sky cover	8	92	175	7.52
089	11/04/86	2001	Mostly clear	0.10	sky cover	8	92	175	7.52
095	11/04/86	2100	Mostly Clear	0.10	sky cover	8	92	175	7.52
101	11/04/86	2200	Mostly Clear	0.10	sky cover	8	92	175	7.52
107	11/04/86	2300	Clear	0.00	sky cover	8	92	175	7.52
113	11/04/86	0000	Clear	0.00	sky cover	8	92	175	7.52
119	11/04/86	0059	Clear	0.00	sky cover	8	92	175	7.52
125	11/04/86	0200	Clear	0.00	sky cover	8	92	175	7.52
133	11/04/86	0300	Clear	0.00	sky cover	8	92	175	7.52
141	11/04/86	0359	Clear	0.00	sky cover	8	92	175	7.52
147	11/04/86	0500	Overcast	1.00	sky cover	8	92	175	7.52
153	11/04/86	0600	Overcast	1.00	sky cover	8	92	175	7.52

TABLE 4.1 Image Parameter Inputs for Infrared Images, Continued

The following data details each of the infrared image files processed by KRC to create texture segment files. Image files are referenced by their frame number, indicated by the "EXT" column below.

Page 2 of 2

EXT	TCALIB	WAVEBND	DYN	GLV	ATMP
nnn	0.nnnn	8-12um	cnt	int	real
001	0.11	8-12um	256	76	-5.4
007	0.11	8-12um	256	80	-5.8
012	0.24	8-12um	256	133	-5.7
017	0.24	8-12um	256	170	-4.4
023	0.26	8-12um	256	153	-2.9
028	0.26	8-12um	256	147	-1.5
035	0.12	8-12um	256	118	0.9
041	0.083	8-12um	256	103	1.6
047	0.27	8-12um	256	90	2.4
053	0.56	8-12um	256	94	2.5
059	0.034	8-12um	256	110	2.6
061	0.059	8-12um	256	101	2.5
067	0.24	8-12um	256	111	0.3
073	0.17	8-12um	256	99	-2.0
081	0.32	8-12um	256	113	-2.5
089	0.12	8-12um	256	130	-1.6
095	0.19	8-12um	256	108	-2.1
101	0.40	8-12um	256	102	-1.4
107	0.11	8-12um	256	103	-2.3
113	0.048	8-12um	256	111	-1.8
119	0.068	8-12um	256	113	-1.8
125	0.082	8-12um	256	115	-1.8
133	0.046	8-12um	256	112	-1.8
141	0.057	8-12um	256	119	-1.2
147	0.018	8-12um	256	90	-1.0
153	0.0039	8-12um	256	86	-0.2

TABLE 4.2 Image Texture Segment File Inputs

Two texture segment files were created from each of the image files described in Table 4.1. Texture segment file names in the format FVI86nnn.S0x specify a Frame from Standard Scene VI taken in 1986, frame number nnn (corresponding to the "EXT" numbers listed in Table 4.1). The filename extension indicates a Segment of type x where x=1 is trees, and x=2 is the grassy foreground.

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FILENAME	ANGL	RNGM	TEXTURE DESCRIPTION	ROW	COL
FVI86nnn.S0x	deg	int	xx	cnt	cnt
FVI86001.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86001.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86007.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86007.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86012.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86012.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86017.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86017.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86023.S01	-7.01	221	BARE TREES AT FIELD EDGE	18	58
FVI86023.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86028.S01	-7.01	221	BARE TREES AT FIELD EDGE	18	58
FVI86028.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86035.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86035.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86041.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86041.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86047.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86047.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86053.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86053.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86059.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86059.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86061.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86061.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86067.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86067.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86073.S01	-7.01	221	BARE TREES AT FIELD EDGE	18	58
FVI86073.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	18	58
FVI86081.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86081.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86089.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86089.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	18	58
FVI86095.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86095.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86101.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86101.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58

TABLE 4.2 Image Texture Segment File Inputs, Continued

Two texture segment files were created from each of the image files described in Table 4.1. Texture segment file names in the format FVI86nnn.S0x specify a Frame from Standard Scene VI taken in 1986, frame number nnn (corresponding to the "EXT" numbers listed in Table 4.1). The filename extension indicates a Segment of type x where x=1 is trees, and x=2 is the grassy foreground.

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FILENAME	ANGL	RNGM	TEXTURE DESCRIPTION	ROW	COL
FVI86nnn.S0x	deg	int	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	cnt	cnt
FVI86107.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86107.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86113.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86113.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	18	58
FVI86119.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86119.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86125.S01	-7.01	221	BARE TREES AT FIELD EDGE	18	58
FVI86125.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86133.S01	-7.01	221	BARE TREES AT FIELD EDGE	18	58
FVI86133.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	18	58
FVI86141.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86141.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58
FVI86147.S01	-7.01	221	BARE TREES AT FIELD EDGE	17	58
FVI86147.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	18	58
FVI86153.S01	-7.01	221	ROW OF BARE TREES AT FIELD EDGE	17	58
FVI86153.S02	80.74	202	FOREGROUND FIELD OF TALL GRASS	17	58

TABLE 4.3 Image Texture Statistics Output Files

A unique output file of texture statistics was generated for each texture segment file. Names of texture segment input files and their corresponding statistics output files are shown. The ".SPS" extension on the output file is automatically generated by the KRCMEZ program.

Page 1 of 2

INPUT FILENAME	OUTPUT FILENAME
FVI86nnn.S0x	FVI86nnn.SPS
FVI86001.S01	FVI86001.SPS
FVI86001.S02	FVI86002.SPS
FVI86007.S01	FVI86007.SPS
FVI86007.S02	FVI86008.SPS
FVI86012.S01	FVI86012.SPS
FVI86012.S02	FVI86013.SPS
FVI86017.S01	FVI86017.SPS
FVI86017.S02	FVI86018.SPS
FVI86023.S01	FVI86023.SPS
FVI86023.S02	FVI86024.SPS
FVI86028.S01	FVI86028.SPS
FVI86028.S02	FVI86029.SPS
FVI86035.S01	FVI86035.SPS
FVI86035.S02	FVI86036.SPS
FVI86041.S01	FVI86041.SPS
FVI86041.S02	FVI86042.SPS
FVI86047.S01	FVI86047.SPS
FVI86047.S02	FVI86048.SPS
FVI86053.S01	FVI86053.SPS
FVI86053.S02	FVI86054.SPS
FVI86059.S01	FVI86059.SPS
FVI86059.S02	FVI86060.SPS
FVI86061.S01	FVI86061.SPS
FVI86061.S02	FVI86062.SPS
FVI86067.S01	FVI86067.SPS
FVI86067.S02	FVI86068.SPS
FVI86073.S01	FVI86073.SPS
FVI86073.S02	FVI86074.SPS
FVI86081.S01	FVI86081.SPS
FVI86081.S02	FVI86082.SPS
FVI86089.S01	FVI86089.SPS
FVI86089.S02	FVI86090.SPS
FVI86095.S01	FVI86095.SPS
FVI86095.S02	FVI86096.SPS
FVI86101.S01	FVI86101.SPS
FVI86101.S02	FVI86102.SPS

TABLE 4.3 Image Texture Statistics Output Files, Continued

A unique output file of texture statistics was generated for each texture segment file. Names of texture segment input files and their corresponding statistics output files are shown. The ".SPS" extension on the output file is automatically generated by the KRCMEZ program.

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INPUT FILENAME	OUTPUT FILENAME
FVI86nnn.S0x	FVI86nnn.SPS
FVI86107.S01	FVI86107.SPS
FVI86107.S02	FVI86108.SPS
FVI86113.S01	FVI86113.SPS
FVI86113.S02	FVI86114.SPS
FVI86119.S01	FVI86119.SPS
FVI86119.S02	FVI86120.SPS
FVI86125.S01	FVI86125.SPS
FVI86125.S02	FVI86126.SPS
FVI86133.S01	FVI86133.SPS
FVI86133.S02	FVI86134.SPS
FVI86141.S01	FVI86141.SPS
FVI86141.S02	FVI86142.SPS
FVI86147.S01	FVI86147.SPS
FVI86147.S02	FVI86148.SPS
FVI86153.S01	FVI86153.SPS
FVI86153.S02	FVI86154.SPS

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Keweenaw Research Center (KRC) participation in the Basic Technology Initiative Smart Weapons Operability Enhancement (BTI/SWOE) Program, including contributions in the program's three primary developmental areas, are reported and summarized. In the area of background measurement and characterization, data and results from KRC participation in the 1990 Forest Ecosystem Dynamics - Multisensor Aircraft Campaign (FED MAC) are presented. FED MAC data and KRC Standard Scenes data were prepared for incorporation to the information data base being established by the BTI/SWOE program. The Physically Reasonable Infrared Signature Model (PRISM), developed by KRC, was made available to the BTI/SWOE modeling effort. Work with software for calculating scene statistics and metrics for infrared imagery is described. Recent developments of PRISM and of image processing software are summarized.					
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